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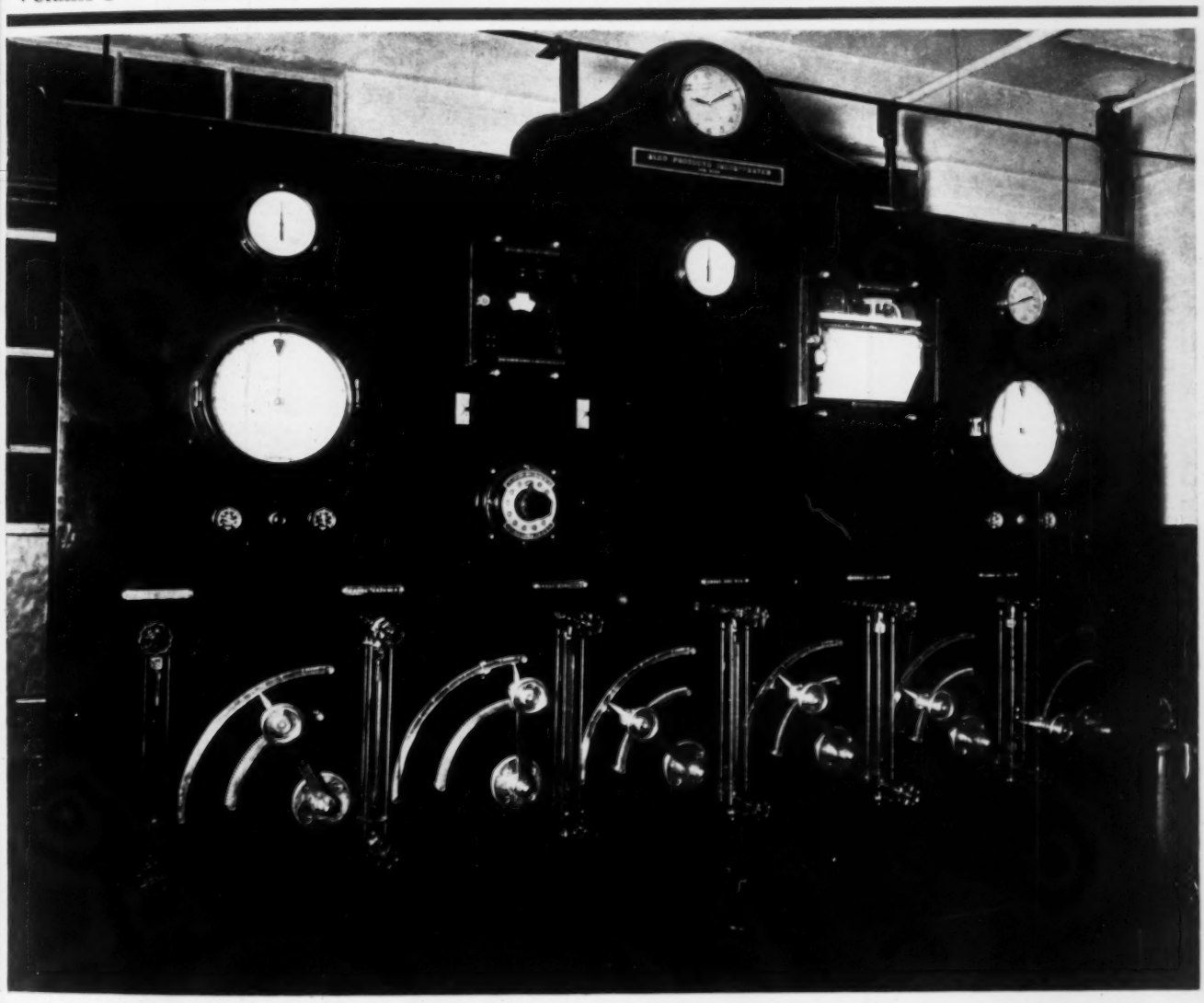
INSTRUMENTS

THE MAGAZINE OF

MEASUREMENT AND CONTROL

Volume 8 MARCH 1935 Number 3



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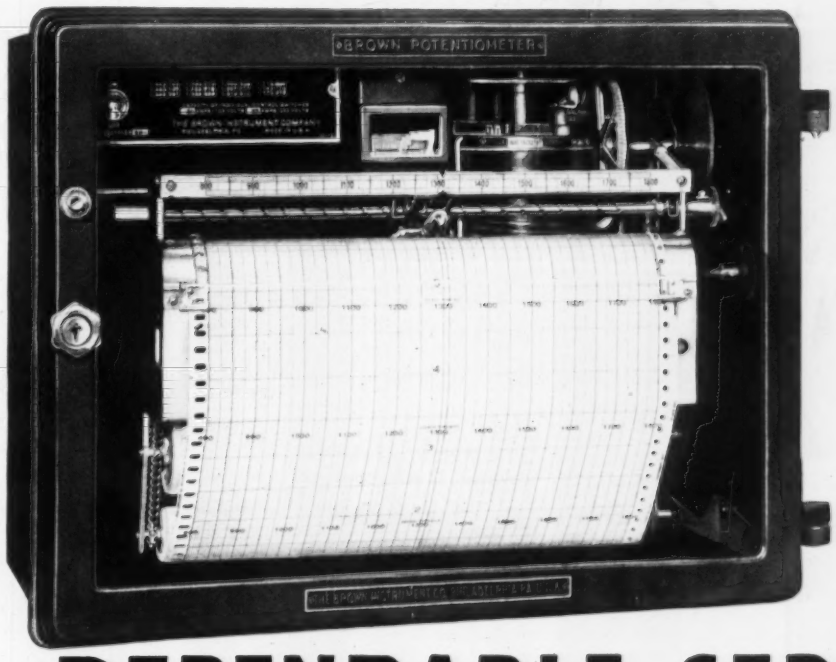
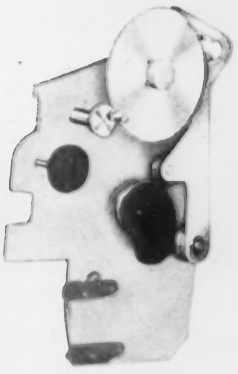
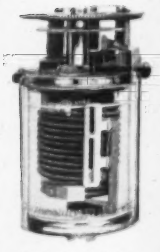




Drive Mechanism



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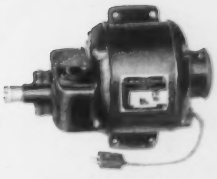

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INSTRUMENTS

THE MAGAZINE of MEASUREMENT and CONTROL

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Courtesy The Foxboro Co.

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MODEL 709
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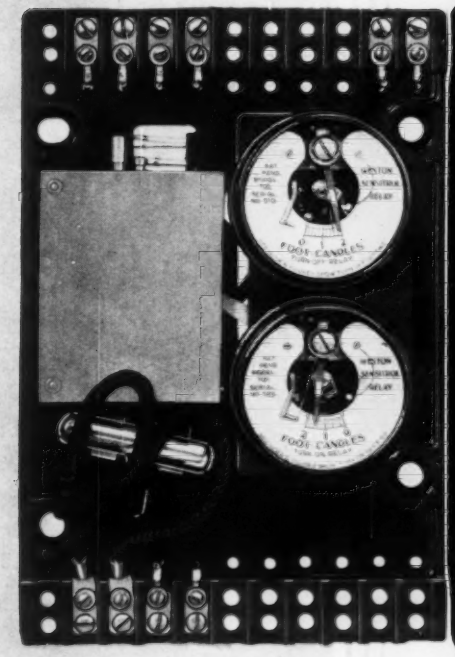

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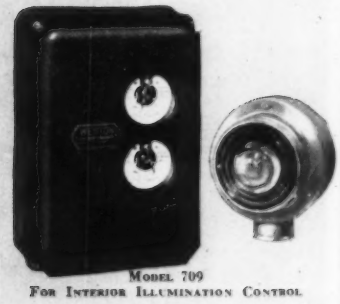

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...ifferent taper and the consequent dead ...ound the bulb will cause considerable lag; or ...ll take a "500-lb." pressure-spring and dip it in ...til it gives the desired deflection at only 150 lbs. ... yet, he will guess at the quantity of filling—which ...e case of SO_2 for instance is an exact amount known ...e maker—with the result that the scale will only be ...ect at one point (two at the most); or he will "evacu... a vapor-pressure system by heating the bulb; or he ...ubstitute alcohol for a nitrogen filling, . . . etc.

M. F. BEHAR

Instrument Scale Distribution and its Effect on Observational Errors

By R. G. JEWELL*

CERTAIN electrical indicating instruments have uniformly divided scales while others have scales which are open over one portion and constricted over another portion, as shown in Fig. 1. The purpose of this paper is to show what factors affect the distribution and to determine what effect the distribution has upon observational errors.

SCALE DISTRIBUTION CONTROL

In every electrical indicating instrument there is an actuating torque and a restoring torque. The actuating torque tends to move the pointer up scale and the restoring torque tends to move the pointer down scale. The manner in which these torques vary with the current and the pointer deflection determines the scale distribution. In some instruments both the actuating and restoring torques are electrical in nature while in other instruments the restoring torque is provided by a spiral spring. The latter case lends itself more readily to analysis and will be the only one discussed in this paper.

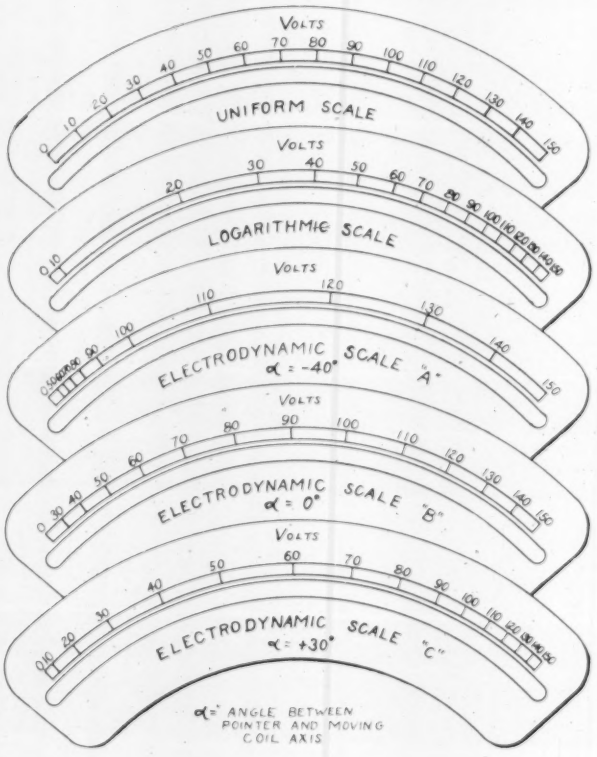
VOLTS
UNIFORM SCALE
LOGARITHMIC SCALE
ELECTRODYNAMIC SCALE "A" α = -40°
ELECTRODYNAMIC SCALE "B" α = 0°
ELECTRODYNAMIC SCALE "C" α = +30°
α = ANGLE BETWEEN POINTER AND MOVING COIL AXIS

Fig. 1. A few scale distributions.

The torque T of the restoring system is given by the product of the spring constant K and the pointer deflection; hence

$$T = KD \quad . \quad . \quad . \quad . \quad (1)$$

The torque of the actuating system is dependent upon the rate of energy change in the system with respect to the pointer deflection D and is equal to $K_1\ dE/dD$ where K_1 is a constant of proportionality. The torques of the actuating and restoring systems are equal in magnitude when the pointer is at rest.

The energy of the actuating system is electromagnetic and is expressed by

$$E = K_2 \phi I_2 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

for d'Arsonval (permanent-magnet moving-coil) systems;

$$E = 1/2\ L_1 I_1^2 + 1/2\ L_2 I_2^2 - M \cos (\gamma + \alpha + D)\ I_1 I_2 \cos \theta \quad . \quad . \quad . \quad . \quad (3)$$

for electrodynamic systems where the coil axes lie in one plane; and

$$E = 1/2\ L_1 I_1^2 \quad . \quad . \quad . \quad . \quad . \quad (4)$$

for iron vane systems; where E is the energy of the system; L_1 is the field coil inductance; L_2 is the armature coil inductance; I_1 is the field coil current; I_2 is the armature coil current; M is the value of the mutual inductance between the field and armature coils when the angle between their axes is zero (see Fig. 2); γ, α, and D are angles as shown in Fig. 2; θ is the phase angle between the field current I_1 and armature current I_2; K_1 is a constant of proportionality, and ϕ is the field flux enclosed by the armature coil.

Hence

$$T = KD = K_1\ dE/dD = K_2 I_2\ d\phi/dD \quad . \quad (5)$$

for the d'Arsonval system;

$$= K_1 \sin (\gamma + \alpha + D)\ I_1 I_2 \cos \theta \quad (6)$$

for electrodynamic instruments;

$$= K_3 I_1^2\ dL_1/dD \quad (7)$$

for the iron vane instruments; where K_2, K_4, and K_3 are constants.

These equations are also stated by Drysdale in his paper "Future Progress in Electrical Measuring Instruments."

SCALE DISTRIBUTION FOR THE D'ARSONVAL SYSTEM

In a d'Arsonval system the flux linking the armature coil varies directly with the pointer deflection D so that equation (5) reduces to

$$D = K_6 I_2 \quad . \quad (8)$$

which shows that the pointer deflection is directly proportional to the armature current. The scale distribution is therefore uniform.

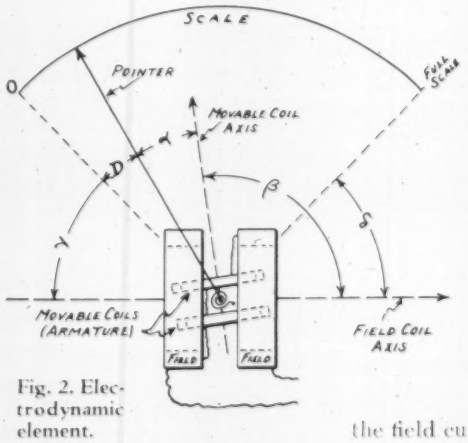

Fig. 2. Electrodynamic element.

SCALE DISTRIBUTION OF THE ELECTRODYNAMIC SYSTEM

The simplest electrodynamic system to consider is the voltmeter in which the field current I_1 and armature current I_2 are equal, in phase, and proportional to the applied voltage V. Equation (6) then reduces to

$$KD = K_6 V^2 \sin (\gamma + \alpha + D). \quad . \quad . \quad (9)$$

Solving equation (9) for V,

$$V = \sqrt{K/K_6}\ \sqrt{D}\ \sin (\gamma + \alpha + D) \quad (10)$$

In order to get a better understanding of the procedure in constructing a scale, a specific example will be worked out with the following constants

*Meter and Instrument Engineering Department, General Electric Co., West Lynn, Mass.

Full scale voltage V_{FS} . . . . . = 150
Full scale deflection D_{FS}, deg. . . . . = 90
Angle (α) between pointer and armature coil axis = 0
Angle (γ) between field coil axis and zero of scale, deg. . . . . = 45

The value of the coefficient $\sqrt{K K_0}$ is determined by substituting the conditions at full scale in equation (10). The coefficient for the above set of conditions is 13.3; hence equation (10) becomes

$$V = 13.3 \sqrt{D / \sin (45 + D)} \quad (11)$$

Substituting various values of D in equation (11) and plotting the results gives the curve of Fig. 3 from which the deflection D can be found for any voltage. The values of D corresponding to the main voltage divisions are then laid off graphically on the arc of a circle and the voltage values marked. The result is a scale as shown in Fig. 4. Fig. 4 also compares the actual with the constructed scale and shows close agreement.

Returning to equation (10) it is seen that the distribution is affected only by the angle (γ) between the zero line and the field coil axis and angle (α) between the pointer and movable coil axis.

Inspection of Fig. 2 reveals that when the angle (α) between the pointer and movable coil axis is negative and equal to (γ) and the pointer is on zero, the movable and stationary coil axes are oppositely directed and produce an unstable condition thereby setting one limit for the value of (α). The other limit for (α) is found when the pointer is at full scale, for then if (α) is equal to (δ) the movable and stationary coil axes are in the same direction and no torque is produced.

Returning to Fig. 1 it is seen that distribution A was obtained with (α) equal to −40 degrees and distribution C with (α) equal to +30 degrees. These two values represent the practical limits. Instability at zero results from values less than −40 degrees. Low sensitivity results from values greater than +30 degrees.

The possible distribution on an electrodynamic instrument is therefore seen to be definite and limited in variability.

SCALE DISTRIBUTION OF THE IRON VANE SYSTEM

An equation for an iron vane system showing the relation between the inductance L_1 and the deflection D can take many forms depending upon the physical arrangement of the parts. If the equation for the inductance is known it can be substituted in equation (7) and the scale can be constructed in a manner similar to the above example for the electrodynamic system.

The inductance equation is not known in many cases and then the inductance-deflection curve must be used. The slope of the tangent to the curve for a given pointer deflection D is substituted in equation (7) for dL_1/dD together with the corresponding value of D. The value of I_1 is then determined and by plotting I_1 against the pointer deflection D a curve similar to Fig. 3 is obtained from which the scale can be constructed similarly to the foregoing example for electrodynamic instruments.

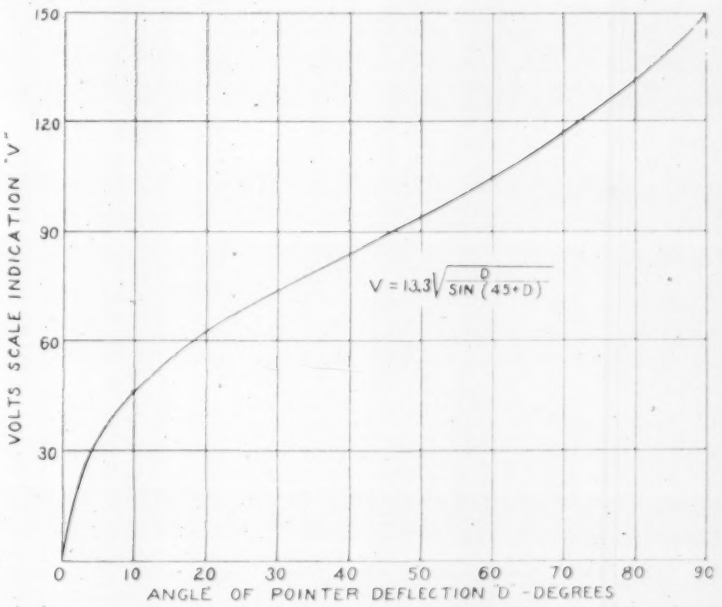

Fig. 3. Relation between pointer deflection and volts scale indication.

The logarithmic scale shown in Fig. 1 could be obtained with an iron vane system by properly shaping and placing the parts. The scale is logarithmic from 10 to full scale but in order to get zero the scale must obey some other law as zero is approached.

EFFECT OF SCALE DISTRIBUTION ON OBSERVATIONAL ERRORS

No matter how good the inherent accuracy of an instrument is, there always is a certain amount of error introduced by the observer who is not able to read the exact indication of the pointer. The error introduced will, of course, be influenced by the size of the pointer, parallax, pointer position with respect to the extremities of the division, and by the observer.

For purposes of discussion it is necessary to take some average value by which the observed and actual positions of the pointer might differ. A value of 0.005 inch is common even with a blade pointer and mirror to minimize parallax. The resulting error in per cent indication is dependent on the scale distribution and pointer deflection.

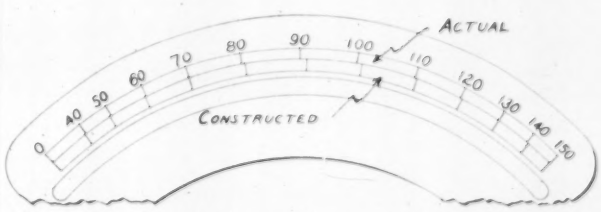

Fig. 4. Electrodynamic type voltmeter. 150-volt—90-degree scale. Actual and constructed scales for $\alpha = 0$.

Various scale distributions are shown in Fig. 1. The observational errors introduced by the above 0.005 inch are shown in Fig. 5 and 6 for each of the scales.

Fig. 5 shows the observational errors plotted against the pointer deflections in inches. The outstanding characteristic is the manner in which the error decreases as the pointer moves up scale over the first third of the scale length. With the exception of the logarithmic scale, readings should never be taken on the lower third of the scale length for maximum accuracy. The logarithmic scale has the advantage that it can be read with the same

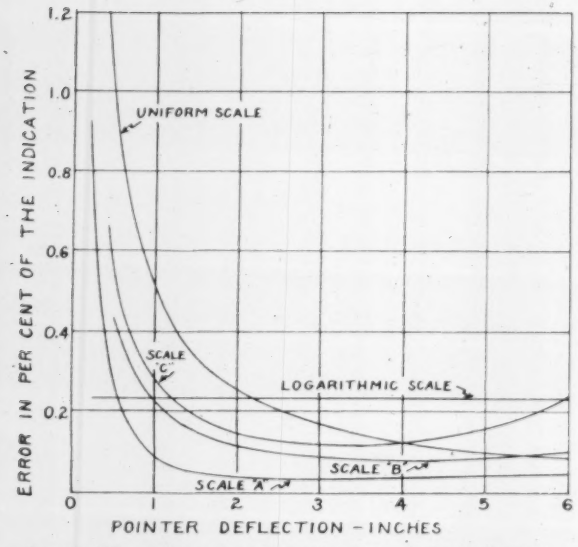

Fig. 5. Observational error in percent of the indication caused by an error of 0.005 inch on a 6-inch scale for various scale distributions as a function of the pointer deflection measured in inches.

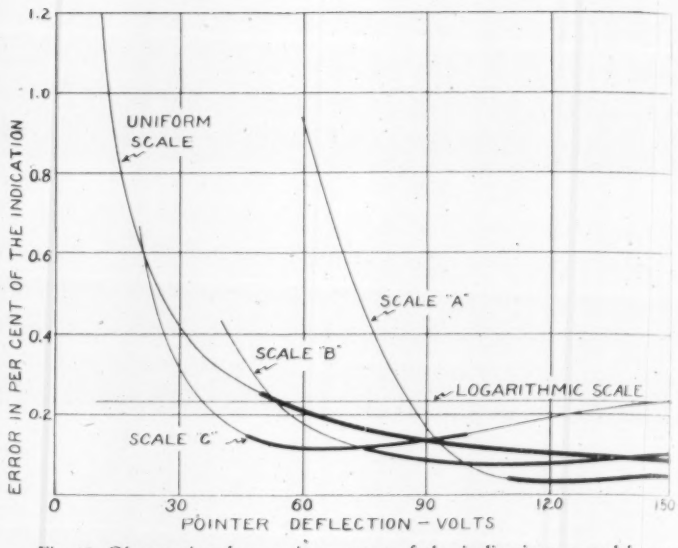

Fig. 6. Observational error in percent of the indication caused by an error of 0.005 inch on a 6-inch scale for various scale distributions as a function of the pointer deflection measured in volts. Heavy lines show scale regions which are "open" and above one-third of the scale length.

accuracy over practically the whole scale but the error is much greater over the upper two-thirds of the scale length than for the other types of distributions.

It is to be noted that for the same observational errors the uniform scale cannot be read as far down on the scale (measured in inches) as can the other scales shown in Fig. 1. A safe rule to follow for all scales is "Always use the upper two-thirds of the scale length."

The observational error plotted against the pointer deflection in volts is shown in Fig. 6. The smallest errors are obtained on that portion of the scales which is "open" and above one-third of the scale length as shown by the heavy part of the curves. Scale "A" gives the smallest errors of any of the scales shown, but the usable range is not as great as for the other scales. Such an instrument would be suitable for laboratory use where accuracy is more important than a long usable range, the range being covered by having a sufficient number of instuments.

Scale distribution "B," while not capable of giving as much accuracy as scale "A," has the advantage of a greater range and would be better adapted to general usage in test work.

Distribution "C" is another short range scale, the useful part being the middle third. An application would be a case where the measured magnitude fluctuates above the values where readings are taken. The pointer would not strike against the upper stop on the peak of the fluctuations. Scale "C" is therefore seen to have a limited application and would not ordinarily be used.

The errors shown by the curves are in percent of the indication. The instrument user is interested in the accuracy of the measurement and it is for this reason that the errors are shown in percent of the indication. Manufacturers state the accuracy of instruments in percent of full scale. This manner of expressing the accuracy is necessary. It has been pointed out that the observational errors are not the same on all portions of the scale and it is not justifiable to expect the accuracy to be the same on all portions of the scale when expressed in percent of the indication. It therefore is necessary to refer to a definite point on the scale when stating the accuracy. The full-scale point is the most obvious point to select.

CONCLUSIONS

The scale distribution of an electrical indicating instrument is controlled by the physical structure of the instrument and can be predetermined by considering the manner in which the actuating and restoring torques vary with the current and the pointer deflection.

The distribution can be varied in certain cases by simply changing the angle between the armature coil and pointer. The possible range in scale distribution change is limited by instability and loss of sensitivity.

Observational errors are minimized by using an instrument having a scale which is open in the region where readings are to be taken. However, readings should never be taken on the lower third of the scale length excepting on logarithmic scales. The observational error on a logarithmic scale is constant over the scale range but is higher than for the other types of scales over the recommended range. A safe rule to follow when using any instrument is "Use the upper two-thirds of the scale length."

BIBLIOGRAPHY—SCALE LAW & ERRORS

(Prepared by the Main Library of the General Electric Co. and the National Bureau of Standards)

1934

[1]P. A. Borden and M. F. Béhar. Electrical Measuring Elements and Scales. *Instruments*, Vol. 7, March 1934, pages 45-57. Includes a brief discussion of the scale law, pages 55-57.

1933

[2]B. M. Dávies. Machine for Dividing Scales of Varying Increment. *Journal of Scientific Instruments*, Vol. 10, October 1933, pages 314-18.

[3]C. V. Drysdale. Future Progress in Electrical Measuring Instruments. *Journal of the Institution of Electrical Engineers* (London), Vol. 72, May 1933, pages 365-384.

[4]K. Edgcumbe and F. E. J. Ockenden. Industrial Electrical Measuring Instruments (book). Pitman, London and New York, 1933. Nine sub-heads under "Scale Shape" in index.

1931

[5]J. L. Ferns. Torque in Instruments. *The Electrical Review*, Vol. 109, July 1931, page 167. Explains theory of deriving characteristics of moving-iron and dynamometer type instruments; derives equation for calculating torque.

1930

[6]H. Baeckstroem. Decimal Equation Reading of Scales. (In German.) *Zeitschrift für Instrumentenkunde*, Vol. 50, December 1930, pages 669-79. "Calculation of average error from complete series of observations; influence of number of observation on decimal frequency, and of non-uniform division on exactness."—Engineering Index

[7]H. Baeckstroem. Decimal Equation Reading of Scales. (In German.) *Zeitschrift für Instrumentenkunde*, Vol. 50, November 1930, pages 699-724. "Subjective division of scale interval; symmetry of subjective interval at various location of division; calculation of corrections; series of experiments by Grossman; calculation of average error."—Engineering Index

(Continued on page 79)

Relays Find Important Applications on Modern Aircraft

Increasing Use of Electrical Equipment Opens Up a New Field of Instrumentation

By JACK DELMONTE*

THE past three or four years have witnessed a large increase of electrical applications on aircraft. From the earliest days of airplane development there was a need for electricity. The spark plugs on the engines required a source of electrical potential for their firing, and hence magnetos were developed to provide the high voltages necessary. As the magnetos could fulfill only this function, storage batteries were added to the plane's equipment. Though these added considerably to the weight of the plane's accessories, they were a distinct asset in providing low voltage for the exterior lighting system of the airplane during night flight. The lighting system, supplied at 12 volts, includes the running lights, the landing lights, the identification lights, the anchor lights, and the turtleback lights. More recently, the storage battery has been called upon to facilitate the starting of the airplane engine by furnishing large currents to the electrical starter.

The demand for communication facilities brought the radio to aviation, this step gathering momentum during the past few years. Aircraft radios were furnished in a number of types and sizes, depending upon the requirements. Rather than rely upon heavy batteries with limited supplies of energy, electrical generators were introduced to supply the radio demand. Though generators had been in use before on airplanes, for charging the storage batteries, new designs were evolved to meet both the battery and the radio requirements simultaneously. This step required a careful design of generating apparatus: as light as possible and not too bulky. At the same time the functions of the electrical equipment required a consistent and reliable supply of energy. This fact cannot be overemphasized when one realizes the dependence of the airplane upon its communications equipment when flying blind. The radio beacons, outlining the "air-paths" about the country, have made the radio and its electrical supply indispensable to safe flying. In addition, the aircraft radio plays an important part in enabling the airplanes to maintain contact with ships at sea. As a matter of fact, the aircraft tactics were developed on the assumption that communications apparatus may be relied upon in all exigencies.

Trends in electrical applications point to small motors and additional controlling devices as possible additional consumers of electrical energy. In short, the extent of electrical equipment on the airplane is increasing, and under the exactitudes of service conditions the equipment and its electrical supply must have protection against damage. In this capacity relays have been introduced with very good results. The relays not only protect the equipment, but also minimize fire hazards.

The present trend is toward the adoption of engine-driven aircraft generators. To maintain an electrical supply with a low voltage regulation is no small task under service conditions. The generator may be expected to rotate at any speed up to 4000 r.p.m. The high rotational speeds are reached when the craft is in a dive and the lower speeds as the engine approaches idling. This fact must be coupled with a realization that reliability is expected of the electrical system in extremes of environment as: tropical heats; freezing temperatures of arctic regions; high altitudes (usual ceiling 25,000 feet); corrosive sea atmospheres; and, as a climax, the shocks and stresses of the airplane during all its flight manoeuvres. Such service conditions furnish a test that will try the mettle of the electrical system.

To supply the high plate potentials of the radio tubes and the low voltage filament circuits, double-voltage d.c. generators were developed. The generators are self-excited through the low-voltage supply. The curves in Fig. 1 show the typical voltage regulation obtained for a radio generator. A voltage regulator in the low-voltage

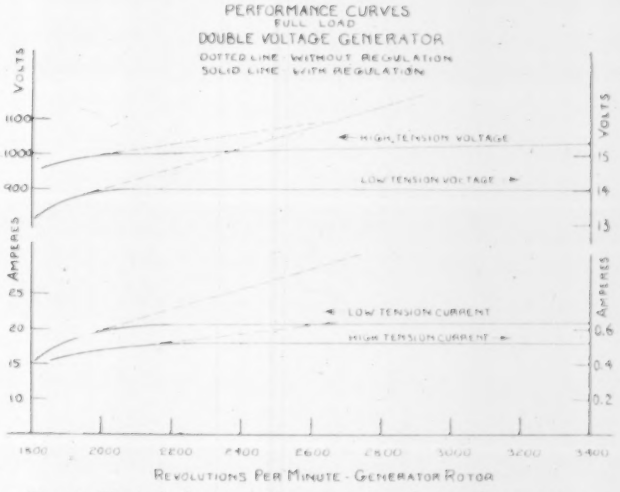

Fig. 1. Typical electrical characteristics of aircraft generators.

circuit alternately cuts in and removes resistance from the shunt field of the generator, regulating the low and the high voltages. The dotted curves show the trend of the voltages had there not been some measure of control. The voltage regulation for the low-voltage circuit and for the high-voltage circuit are in keeping with practical requirements.

A closer examination of the low-voltage circuit will suggest the conventional methods of protection. The terminal voltage of the generator averages about 14.0 volts and the storage batteries placed across the terminals are rated at about 12.5 volts. It is not desirable to have the voltage of the generator rise to too high a value as the battery may become overcharged, causing overheating and shortening the life of the battery. The voltage regulator easily handles this tendency. On the other hand it is a good practice to maintain the lower limit of voltage on the generator by a reverse current relay. If, while the engine is approaching idling speeds, the voltage of the generator drops below that of the battery, the battery will discharge through the generator, reverse the fields, and result in a large drain upon the battery accompanied by excessive circulatory currents. The reverse current relay will break open the circuit at the first tendency to reverse the current. While

(Continued on page 78)

*Junior Electrical Engineer, U. S. Naval Aircraft Factory, Philadelphia, Pa.

All opinions expressed in this article are the personal viewpoints of the author and are not to be construed as of official origin.

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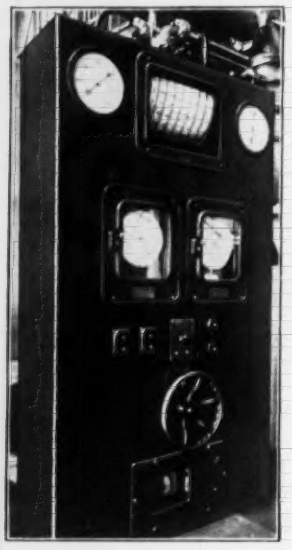

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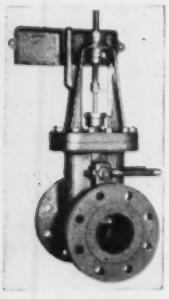

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Electricity Meters

PART ONE

General Characteristics and Single-element Types

By PERRY A. BORDEN† and M. F. BEHAR**

1. Introduction, Definitions, etc.

The term "meter" is often loosely employed to designate any form of electrical measuring device; but in accord with correct usage and standard practice it is applied in this work (except when forming part of a compound word) to describe a measuring device which *integrates*, i.e., which provides a summation of instantaneous values of the magnitude under measurement. From a mathematical standpont it is conceivable that any determinable electrical magnitude may be subjected to integration; and from an engineering standpoint this is feasible; but in practice the process of summation over an interval of time is applied to only two electrical magnitudes: *power*—real or apparent—and, to a lesser degree, *current*. [Note: Volt-hour or volt-squared-hour meters are sometimes used in special applications such as life testing of incandescent lamps.]

Among electrical measuring devices the electricity meter occupies a unique place in that during its time of use it is not under control of the user. It is installed frequently in some obscure location, its mechanism and terminals sealed, and there it is left, perhaps for five or six years* without receiving any attention except for a periodic glance by the meter reader. Yet it is expected to be accurate at all speeds from zero to considerable overload; and since monetary payments are directly based on its registrations (generally without correction) its accuracy must be high.

Meters have engaged the attention of distribution companies, of their technical staffs and of supervisory bodies to a much greater extent than have other types of electrical measuring devices, with the result that many books, reports and technical articles dealing with them have been published; and most of the manufacturers provide excellent descriptive literature. The limited space here available compels a rather superficial treatment of electricity meters.

Definitions

The following definitions applying to watthour meters are taken from the "Code for Electricity Meters," prepared under the joint sponsorship of the Association of Edison Illuminating Companies, the National Electric Light Association and the United States Bureau of Standards:†

(1) *Rotating Element.* That part of the motor element which rotates at a speed proportional to the power integrated by the meter.

(2) *Register.* That part of the meter which registers the revolutions of the rotating element in terms of units of electrical energy.

(3) *Dials.* The graduated circles over which the dial pointers move.

(4) *Register Face.* The part of the register on which the dials are printed.

(5) *Dial Pointers.* Those parts of the register which move over the dials and point to the numbers on the divisions of the dials.

(6) *First Dial.* The graduated circle over which the most rapidly moving dial pointer moves. (Usually the right-hand circle)

*Watthour meters used for billing purposes in Canada must operate under seal of the Dominion Government for a period of six years.

†A. E. S. C. Standard No. C12—1928.

*Fourteenth chapter (XLII) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Béhar's *Manual of Instrumentation*. See editorial announcement of this series on page A7 of November 1933 *Instruments*. A complete chapter of this new handbook is published in each issue of *Instruments* throughout 1934 and 1935. Each chapter is subjected to a final revision, and then set in type, shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright. To be issued in book form on or about Jan. 1, 1936.

†Member A.I.E.E. **Editor, *Instruments*

(7) *Dial Train.* All the gear wheels and pinions used to interconnect the dial pointers.

(8) *Register Ratio.* (R_r) The number of revolutions of the wheel meshing with the worm or pinion on the rotating element for one revolution of the first dial pointer.

(9) *Gear Ratio.* (R_g) The number of revolutions of the rotating element for one revolution of the first dial pointer.

(10) *Register Reading.* The numerical value indicated on the dials by the dial pointers. Neither the register constant nor the test dial, if any exist, is considered.

(11) *Register Constant.* (K_r) The factor used in conjunction with the register reading in order to ascertain the total amount of electrical energy, in the desired unit, that has passed through the meter.

(12) *Standard Register.* One in which each of the four dials is divided into ten equal parts, the division marks being numbered from zero to nine and the gearing between the dial pointers is such that the relative movements of adjacent dial pointers are in opposite directions and in a 10 to 1 ratio. The register constant may be 1, 10 or any power of 10. Nothing appears on the register face in addition to the dials except the word "kilowatthours" and the register constant.

(13) *Registration.* The numerical quantity expressed in the desired unit corresponding in value to the energy that has passed through the meter. It is equal to the product of the register reading and the register constant. The registration during a given interval of time is equal to the product of the register constant and the difference between the register readings at the beginning and the end of the interval.

"Power," "Energy," "Integration," etc.

A few notes on the units to be dealt with, and on the functions of various meters, may be welcomed at this point by readers who may have lost familiarity with the subject since they took electrical courses years before:

A mechanical analogue of an electricity meter which integrates current is a "positive" water meter (a volumetric or gravimetric water meter) in the pipe line to a water-wheel: such a meter merely registers the quantity (volume or weight) passed through it. A mechanical analogue of an electricity meter which integrates power is a positive and piezometric water meter—one with a variable-speed drive interposed between its rotor and its register, so that its register speed will be proportional to the flow and also to the hydraulic head (the "potential" of the water). The first meter will register "pounds" which may be a fair measure of the load if the water is supplied at constant head; the second will register "foot-pounds" or "kilogrammeters" which is a true measure of the hydraulic energy supplied to the water wheel, for it is *the* measure of mechanical energy. The scientific unit of electrical energy is the *joule* (=0.732 ft.-lb.) but the practical unit is the kilowatt-hour (=3,600,000 joules). This unit includes the time term "hour" because the watt is the unit of power, which is the time-rate of energy application. In other words, watts being amperes times volts and amperes being coulombs *per* second, an energy unit including "watt" must specify "*during*" one second or "*in*" any convenient time unit.

Again reverting to mechanics: A reservoir contains so many million *pounds* of water (coulombs). A water wheel is situated so many *feet below* this reservoir (volts) and this hydraulic head is read on a *pressure gage* (voltmeter). The wheel throttle is opened, passing so many *pounds per second* (amperes), which rate is indicated in pounds per second on a simple *flow indicator* (ammeter). There is also installed a two-element flowmeter which combines a flow indicator and a pressure gage to multiply pounds-per-second by pressure; its deflecting pointer travels over a scale graduated in *foot-pounds per second* (watts) and it therefore constitutes a hydraulic *power meter* (wattmeter). It is equipped with a clockwork and drum driving a chart at a constant time rate, so that it constitutes a *curve-drawing power-meter* (recording wattmeter). At the end of so many hours the chart is planimetered, the area —or integration—representing so many foot-pounds per second during so many hours, which can be expressed in two ways: (1) so many water-power-hours or *horse-power-hours* (watthours), or (2) since time cancels out, so many *foot-pounds* (joules). But complication may be saved by installing, instead of a *deflecting* and *recording* hydraulic power INSTRUMENT, the device mentioned in the foregoing paragraph, namely, a *rotating* and *registering* water power METER (watthour meter).

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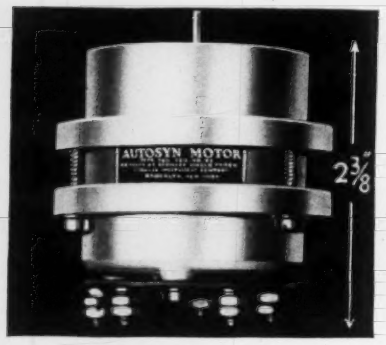

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Principal Types

The history of the development of electricity meters is not only a fascinating subject but an instructive one, because this development represents many beautiful solutions of problems in various branches of electrical and mechanical engineering. It is ably told in some of the works listed in the appended bibliography. We can only touch its highlights: The sale of electrical energy as a commodity dates back to the emergence of electric lighting from a laboratory curiosity to a practical method of illumination. At first there was no thought of measuring *energy* as such. The earliest devices for establishing costs to individual consumers from a common source were *time meters* (about 1872) which registered the time during which the current flowed in the metered circuits, a clock mechanism being electromagnetically released by the current flowing in a small magnet coil. These were followed by *quantity* meters, measuring coulombs or ampere-hours; and it was not until about 1889 that the first *watt-hour* meter, giving an integration of the energy passed through its circuits, appeared in the form of Elihu Thomson's "recording wattmeter." This evolved into one of the modern types, namely the *commutator type*. The other two modern types of watthour meters in widespread use are the *mercury-motor type*, and the *induction type*. The latter had its inception in the Ferraris shifting-field discovery (1885) and was made practical ten years later by Shallenberger. These three principal types of watthour meters, together with the modern *ampere-hour meter*, make up practically the whole field of *rotating-element* (or "motor type") electricity meters in widespread use, to be dealt with in this article.

Features and Characteristics Common to All Types

Before discussing the several types separately it is in order to touch upon the principal features of design and structure, and the principal sources of error and other characteristics, which are common to all rotating-element or motor type d.-c. and a.-c. meters. All such meters are distinguished from indicating and recording instruments by a *register;* and this will be taken up first, in Section 2. In all such meters, too, the values of the *driving torque* and of the *retarding torque* should at all times be such that the momentary speed of the shaft which drives the register will be proportional to the value of the metered magnitude; and this will be briefly discussed in Section 3. Ideal proportionality, and consequent ideal integration (ideally accurate registration at all loads) is unattainable in practice—partly because of *friction*, which will be touched upon in Section 4; but also because of other sources of error inherent in each particular design. Such characteristic (rather than general) error sources will be mentioned under each type; but the *principal adjustments* common to all types will be dealt with in Section 5. Finally, a few words on *bearings* appear in Section 6. Only after this do the descriptions of meters begin. It is assumed that all readers have some acquaintance with electricity meters. Those to whom the subject is entirely new are advised to glance through Sections 7 to 12 (especially Sections 7 and 10) before studying Sections 2 to 6.

2. Registers

The function of a meter being to integrate, its readings are a sum. Except in the case of special meters such as demand meters (next article) which have one pointer advancing up one scale, the "scale" takes the form of a numerical register—usually a group of dials upon which the travel of the rotating member of the meter is progressively indicated by the advance of pointers, each moving continuously in one direction. The reading of the pointers represents the advance of the meter, or the energy consumed, since the pointers were at their zero indication. Hence, in order to obtain the consumption during a specified period of time it becomes necessary to observe the registration at the beginning and at the end of the interval, when the advance during the time will be represented by the difference between the two registrations.

A typical meter register is shown in Fig. 42-1. Each of the four pointers is geared to its neighbor through a 10/1 ratio, so that one revolution of the left-hand pointer represents 1,000 revolutions of the right-hand. For the sake of mechanical simplicity there has been adopted a standard wherein the alternate pointers rotate in opposite directions, but this introduces no difficulty in obtaining correct readings. Between the right-hand spindle and the rotating element of the meter is interposed a gear train of such a ratio that the register of the meter reads units of energy passed through the measuring circuits. In most self-contained meters the reading is direct, *i.e.*, the register reads kilo-

watthours directly; and, where the rating of the meter is so high as to make this impracticable, the gears are so selected that the registration will require to be multipled by 10 or some whole power thereof, which information is distinctly marked on the dial. Many meters produced in foreign countries or manufactured for export to foreign countries, are fitted with cyclometer registers in which individual digits appear behind corresponding openings, as on the Ferranti (English) meter, Fig. 42-2. Though ease of reading may be argued in favor of this type of register, its mechanical complication and non-uniform drag as compared with the dial type has rendered its use practically unknown in American practice.* Fig. 42-3 is the back view of a General

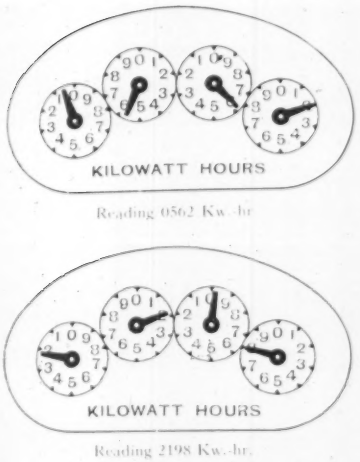


Fig. 41-1

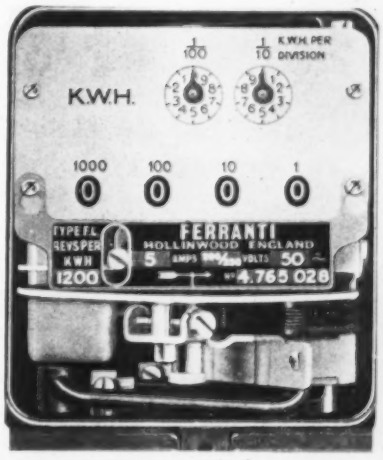


Fig. 41-2

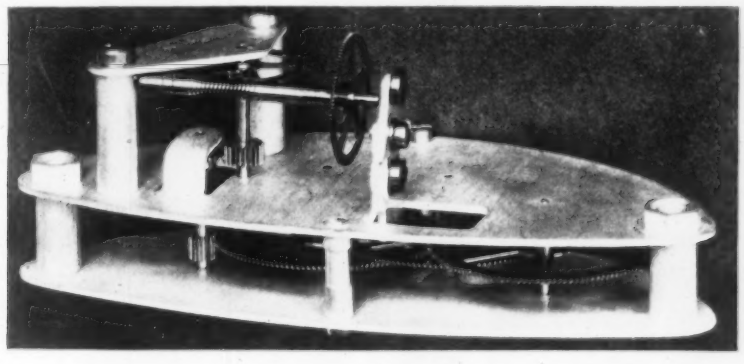


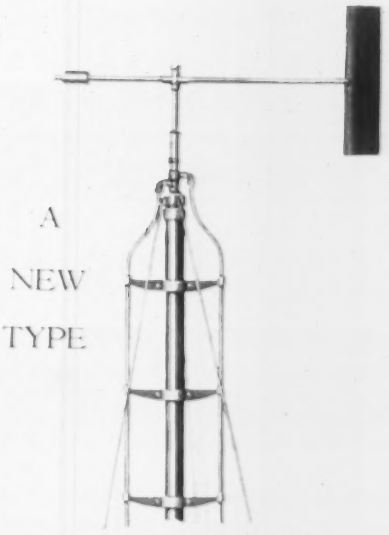
Fig. 41-3

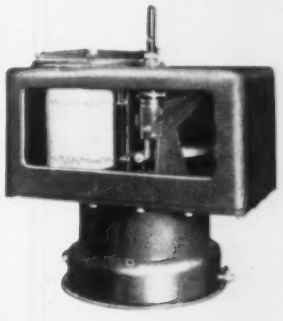
Electric "Form 8" register with a double worm (identified by two grooves near end of shaft) giving a 69 4/9 ratio.

For meters used with shunts or instrument transformers there are several practices in dial marking. Where a metering outfit, including auxiliaries, is purchased outright for a particular installation, it is customary for the manufacturer to equip the meter with a register ratio to read direct, or with a constant of 10 or a whole power thereof. Many utilities and other users of meters, however, prefer a greater degree of flexibility, and obtain their meters to read directly the energy in the meter circuits. Then, when these meters are used with shunts or instrument transformers, as the case may be, the registrations are multipled by a constant determined by the ratio of transformation.

The method of computation for *instrument transformer ratios*, used with wattmeters but equally applicable to watthour meters, was given in the June 1934 article of this series.

*In Part Five of this Manual it was brought out that American engineers prefer cyclometer registers not only on revolution counters and other speed measuring instruments but even on *time* measuring instruments—the very instruments with which dials are traditionally associated. In Part Six it was brought out that, in the field of fluid metering, whereas dial registers survive on *commercial* gas and water meters, cyclometer registers are insistently demanded on *industrial* integrating fluid meters. Not a single American manufacturer of industrial flowmeters standardizes on dial registers for his integrators. Nearly all use cyclometer registers *exclusively*."





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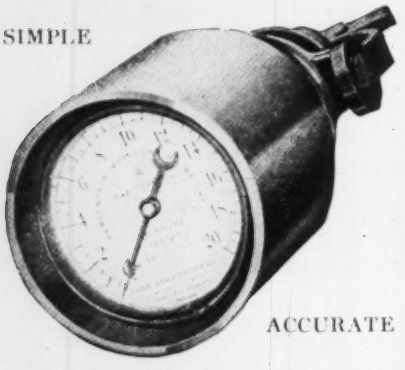

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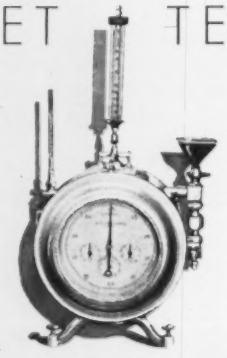

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3. Driving and Retarding Torques

Every electricity meter has its counterpart in an electrical measuring instrument of some deflection type, with respect to the employment of some method whereby an electric magnitude is translated into a mechanical torque: Of the four Basic Principles employed in instruments (see March 1934 article) only one—namely, the electromagnetic principle—is employed in the commonly-used meters; the electrothermal and electrochemical principles were each used in meters that once enjoyed a vogue, and the electrostatic principle never has been (and is not likely ever to be) employed in practical metering.

All electricity meters herein discussed correspond therefore to measuring instruments within the electromagnetic class. Of the numerous deflection types within this class, however, only two employ torque-production principles to which the principles employed in meters correspond exactly. These are (1) the electrodynamometer, wherein two conductors carrying electric current act upon each other with a measurable mechanical force, and (2) the induction type wherein stationary electromagnets are so arranged that an alternating current (of commercial frequency) produces a moving field in an air gap, thereby dragging a rotor of electrically-conducting non-magnetic material. All modern rotating-type electricity meters operate by virtue of one or the other of these two torque-producing principles.

In deflection instrument measuring elements we have an *actuating* torque opposed by a *restoring* torque in such manner that when these two are balanced the pointer or pen-arm comes to rest. In meters, however, the torque due to the metered magnitude must produce continuous rotation of the moving parts, so that instead of a restoring torque we need a braking effect. Hence, the metering terms *driving* torque and *retarding* torque. In a meter, a state of balance between the driving and retarding torques must never cause the register to come to rest except when the metered load is zero; and this balanced condition moreover should result—when a load is being metered—in direct and exact proportionality of speed to load.

The scale of a measuring instrument can be—and that of a precision indicator always is—individually calibrated, and its lower 20% seldom is used; but the only possible "calibration" of a meter register being a change of gear ratio, the proportionality of speed to load should prevail from zero to full load and over.

In a meter, therefore, the driving torque and the retarding torque are equally important. Whatever "law" is followed by the driving element in its relation of torque to load, the braking element should follow a law which will satisfy the conditions of balance set forth above. In a watthour meter having a driving element the driving torque of which is proportional to watts, the retarding torque should be proportional to speed. The speed of the rotating element of such a meter is usually restricted by a damping member consisting of a disk of high-conductivity material (copper or aluminum—the latter preferred) attached to the main shaft and rotating within the air-gap of one or more permanent magnets. The eddy currents set up in the disk by its motion in the magnetic field react in turn upon the field and produce a braking effect proportional to the speed of rotation. The rotating assembly will at all times tend to adjust its speed to the value at which the driving and retarding torques are equal, i.e., a velocity proportional to the power in the circuit. The total distance swept out by a point on the circumference of the disk in a given time thus becomes a summation of the instantaneous velocities in that time, and is proportional to the summation (or integration) of the instantaneous values of power during that time, which represents the energy consumed.

4. Friction and Its Compensation

Although no rotating type meter can have a mechanism from which all friction has been eliminated, this source of error has been admirably minimized. Friction being variable, its minimization improves accuracy because a large friction counter torque would require a correspondingly large compensation, so that the considerably variable *difference* between the two would alone make a meter erratic.

Friction in meters has two components: (1) solid friction and (2) fluid friction. The former has its highest value at the moment of changing from rest to motion ("sticktion") and thereafter generally decreases in absolute value, so that if uncompensated it is *relatively* enormous on changing from no-load to light load, considerable at light load, and relatively insignificant at full load. Fluid friction on the other hand increases as the square of the rotational speed, so that if uncompensated it scarcely affects light-load registration

but slows down the meter noticeably at full load and causes a considerable "overload droop."

In all meters there is solid friction at the bearings. Its value is a function of the moving element's weight (or buoyancy when floated in mercury) and of force components not purely rotational. Its value in mm. g. is relatively high, therefore, in meters with wound armatures (Section 7) and relatively low in both mercury meters (Sections 8 and 9) and induction meters (Section 10), but this value, whatever it be, is generally small in relation to the net actuating torque of the particular type of meter at all loads down to about 5% of rating. (We have reference to modern meters.)

In all meters, too, solid friction exists at twenty-odd places in the register, but the total may be compared to that in a high-grade clock, and it depends on cleanliness, lubrication and temperature as does the friction in a clock.

In commutator type meters (Section 7) there is a much more serious source of solid friction: that of the brushes.

Fluid friction is a function of the size and geometry of the rotating assembly and of the viscosities of the fluids. It exists in two forms: air friction or "windage," and liquid friction. The windage of a cylindrical or spherical wound armature is of course far greater in its absolute value at any given speed than that of a thin disk. The viscosity of air varies but little between extremes of summer and winter temperatures, so that the only variation of windage which must be compensated for is that with speed—the curve shooting up at high loads by reason of the quadratic relation. In mercury meters the liquid friction is high, relatively to windage in other meters, but it is taken into account as a calculated component of the retarding torque. However, the temperature-viscosity characteristic of mercury—unlike that of air—is quite steep in the region between summer and winter extremes (mercury freezing at —40° F.) so that at full-load speed the temperature coefficient of the liquid-friction component in a mercury meter is far from negligible.

Low cost being a requisite of electricity meters, it is impracticable to provide them with a plurality of friction-compensating devices, each having an exactly appropriate speed or temperature characteristic curve. Every modern meter, however, has at least one friction compensation, which consists in applying to the rotating element a forward torque in addition to the driving torque which represents the metered load. In commutator type meters this friction compensator takes the form of an additional field coil acting on the armature; in mercury meters it is a thermocouple generating an additional emf; in induction meters it consists in shading a pole of the voltage electromagnet. These three methods will be described in Sections 7, 8 and 10, but attention is called here to what they all have in common: each is a feature of the potential circuit of the meter; each is operative at all times—at zero load as well as when an overload is being metered.

It is of extreme importance, therefore, that the torque value of the friction compensation should not exceed the light-load value of the total of all meter friction components; for if this should be the case the meter would "creep" on voltage alone: it would register on no-load (and the average consumer would write to the newspapers). Therefore when a load, instead of being switched off, is gradually shut off by a rheostat, the meter will nevertheless stop registering, in spite of the friction-compensating forward torque. But since the value of *starting* friction is generally greater than that of the compensated light-load friction, it is possible for a consumer to apply gradually a light load without causing the meter to start registering. The losses thus represented are trifling, to be sure, but this detail is mentioned in fairness to the utilities.*

Since the value of light-load friction varies unavoidably among different meters, even of the same production lot, and since it tends to increase during years of service, the friction compensation is always so designed and constructed that a meterman can readily *adjust* it in the field.

5. Principal Adjustments

Even a meter having perfectly linear proportionality of load to rotating element speed, regardless of fluctuations in temperature, voltage, etc., would require at least one adjustment: that of its gear ratio, in order that the numerical advance of its register should correspond to the angular advance of its rotating element for that number of units. In such a meter this would be a factory adjustment. In actual meters the most important adjustments, likewise, are the two which relate register speed to load: (1) register speed to rotating

*With which neither of the authors is in any way connected.

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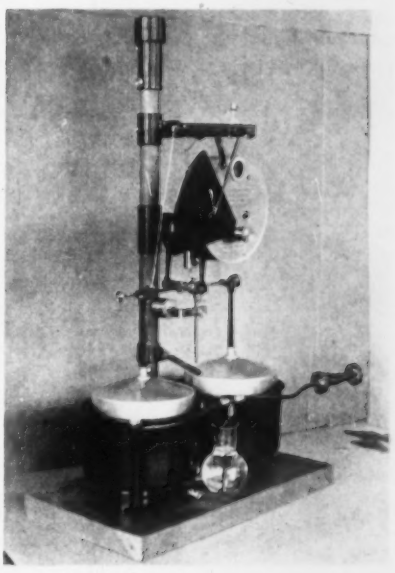

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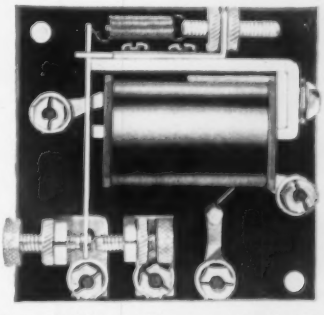

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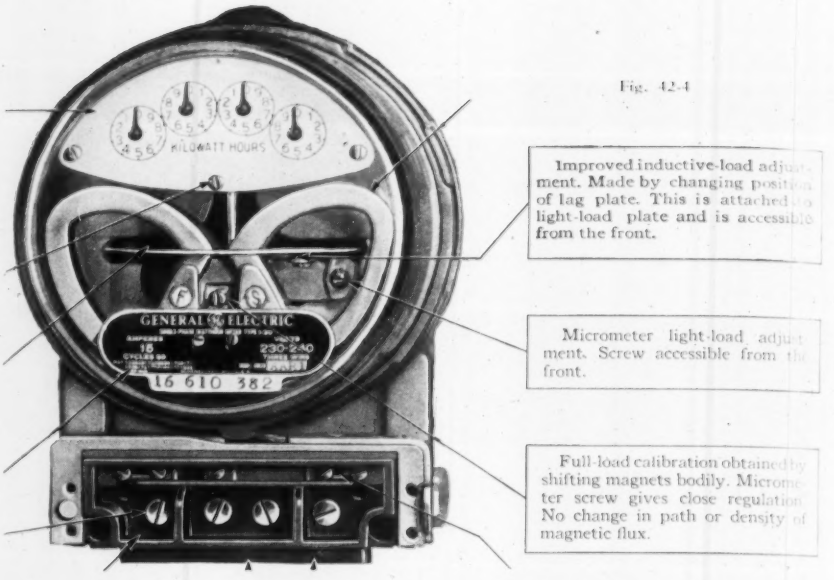
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Fig. 42-4

element speed, and (2) rotating element speed to load. The first is not so much an adjustment (which implies fine gradation) as a change of ratio (by definite increments). The second is the most important field adjustment. It is sometimes called "full-load calibration" and it is "micrometric" in all makes of modern meters—which simply means that a fine-pitch screw is used. Since the speed represents balance of driving torque and retarding torque, this adjustment may consist in varying either, but the most common practice is to adjust the retarding torque. This is accomplished either by shifting the drag magnets radially on the disk, or by diverting more or less of the flux away from the disk by a magnetic shunt positioned by a fine-pitch screw.

The foregoing refers to adjustments which make a meter "faster" or "slower" at practically all loads. The other important adjustments are those affecting only a part of the load range, and they naturally divide themselves into light load, full-load and overload adjustments. Such adjustments are valuable (in some cases absolutely necessary) in order to straighten the otherwise far from linear characteristic curve of quantity-production meters.

Friction compensation (Section 4) is made adjustable and therefore constitutes a light-load adjustment since its forward torque is constant and not proportional to the driving torque.

For full load and overload, a common adjustment consists in utilizing the magnetic shunt idea in the form of small thin plates which become saturated at a certain point, above which any additional flux passes by them.

Fig. 42-4 shows the principal adjustments of an induction-type watthour meter (Section 10) of quite recent construction—this illustration being from a 1935 publication of the General Electric Co.

6. Bearings

Much has been written on the subject of bearings for watthour meters. As a meter must run continuously, it is essential that friction not only be at a minimum but remain reasonably constant in value under all conditions and that the bearings be not subject to abnormal wear in service. In the commutating and induction types of meters the bottom bearing carries the whole weight of the rotating element, while in the mercury-motor type the armature

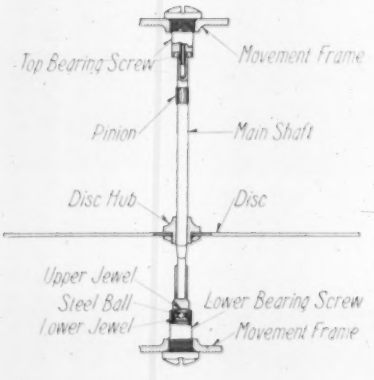


Fig. 42-5

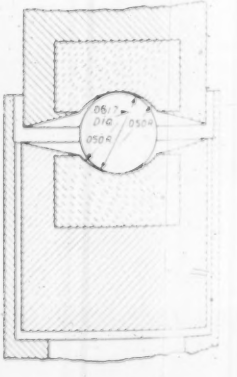


Fig. 42-6

floats and exerts a slight upward pressure on the top bearing. The bearing which carries the weight of the rotor consists generally of a rounded pivot or a steel ball running in a cupped jewel, generally of sapphire. The guide bearing is usually in the form of a polished pin running in a journal which may be of metal or jewelled. The lubrication of meter jewels has been a subject of much controversy but present practice favors sparing lubrication with a high-grade oil especially refined for the purpose. Figs. 42-5 and -6 show the rotating element of a recent Westinghouse induction type meter and its bottom bearing.

7. Commutating Meters

The principle of the Thomson meter of 1888, with modifications and improvements, survives today in the commutator type of meter originally developed for use on a.-c. circuits but now confined almost entirely to d.-c. installations. Essentially it is a small vertical-shaft motor with the familiar arrangement of field and armature—the latter with conventional commutator and brushes—in which motor the driving torque is made proportional to the power at any instant, and with a braking device developing a counter torque proportional to the speed. A diagram of such a meter is shown in Fig. 42-7. Structurally it resembles a d.-c. dynamo without iron in its magnetic circuits. A stationary field coil carries the line current, and the circuit voltage is applied to the rotating armature through a suitable series resistor. The driving element thus becomes a motor having a torque proportional at each instant to the watts in the circuit. The speed of this motor is restricted by a damping disk rotating in the air-gap of one or more permanent magnets so that it will be proportional to the load, as explained in Section 3. For measurement of power in three-wire circuits, this form of meter is provided with a divided current coil as in Fig. 42-8, allowing the currents in both sides of the circuit

Fig. 42-7

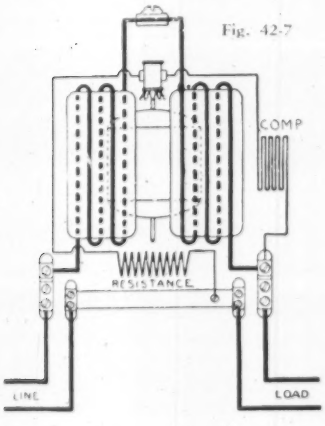
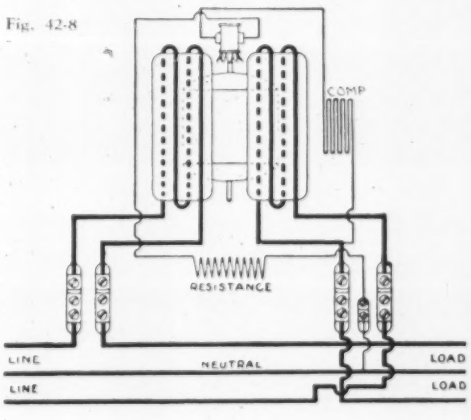


Fig. 42-8



to be passed through the meter, when (assuming a balanced voltage) the whole power in the system will be correctly metered. Friction compensation takes the form of an auxiliary field coil acting on the armature in conjunction with the main field, but connected in circuit (generally in series) with the potential circuit, thus developing a torque at all times. With an absolutely constant voltage on the system and an absolutely constant value of friction, the effect of this coil could be made to provide an exact compensation for the frictional drag; but because of variations in both voltage and friction it becomes necessary to provide a slight margin, so that under conditions of maximum voltage and minimum friction the meter may not "creep" on voltage alone.

As representative of the commutating watthour meter in its most modern form may be mentioned the General Electric Type C-15, shown in Fig. 42-9. The armature is of spherical form, and the circular field coil surrounds it. The friction compensating coil is conspicuously located in front of the motor element, and adjustment of its effect is obtained by moving the coil bodily in relation to the armature. The retarding-torque drag magnets are at the bottom of the meter, and a micrometer adjustment is provided for moving them radially of the disk.

For higher accuracy in three-wire metering (where voltage unbalance is not negligible) or for installation in the presence of stray magnetic fields, there is available a type such as the General Electric CS-3 (Fig. 42-10) in which two electrically independent motor systems act upon a common shaft.

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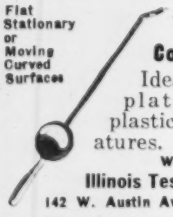

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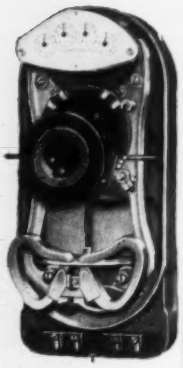


Fig. 42-9

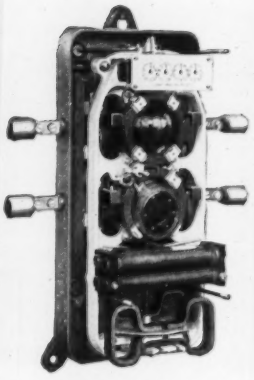


Fig. 42-10

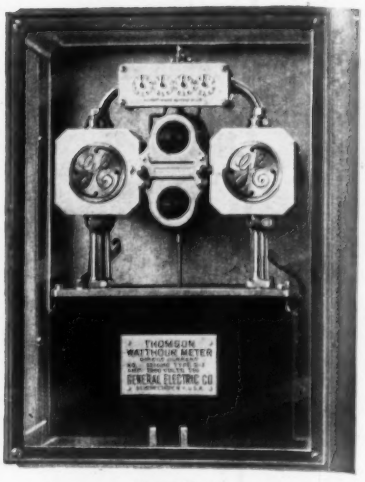


Fig. 42-11

The measuring elements being astatically arranged, stray fields affect them in opposite senses with no resultant error in metering. A further development of the commutating meter, distinctly for heavy switchboard service is found in the G-E Type G-3 (Fig. 42-11) wherein the series "field coil" is a copper bar. This form is built in ratings as high as 6,000 amperes, 600 volts, particularly for electric railway loads.

8. Mercury-motor Type

An obscure laboratory experiment, referred to in physics textbooks as "Barlow's wheel," forms the basis of the principle used in the mercury-motor meter, now probably the most common method of determining the consumption of direct-current energy. The essential part of this meter consists of a copper disk immersed in mercury. A magnetic field passes vertically through the disk—up on one side and down on the other, and an electric current flows through the mercury and traverses the disk in a diametrical sense. The interaction of current and field produces a rotation of the disk with a torque proportional to the product of the two values, so that with the field produced by a potential coil connected across the circuit, and line current (or a definite proportion thereof) passed through a diameter of the disk, there is produced a driving torque representative of the power in the circuit. Drag magnets acting on a damping disk, as in the commutator type meters described above, serve to regulate the speed of rotation, so that the total distance swept out represents the watthours of energy passed through the circuit to which the meter is connected.

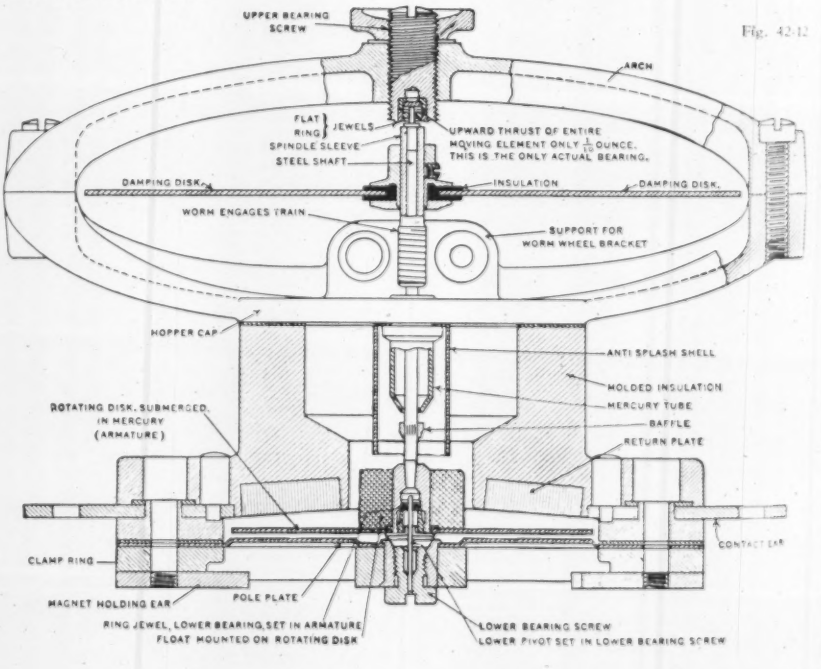


Fig. 42-12

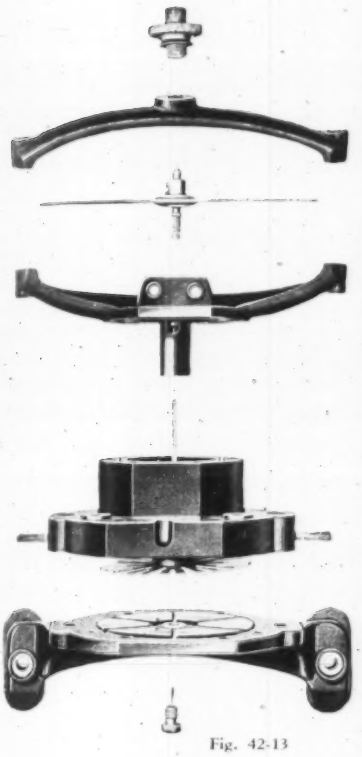


Fig. 42-13

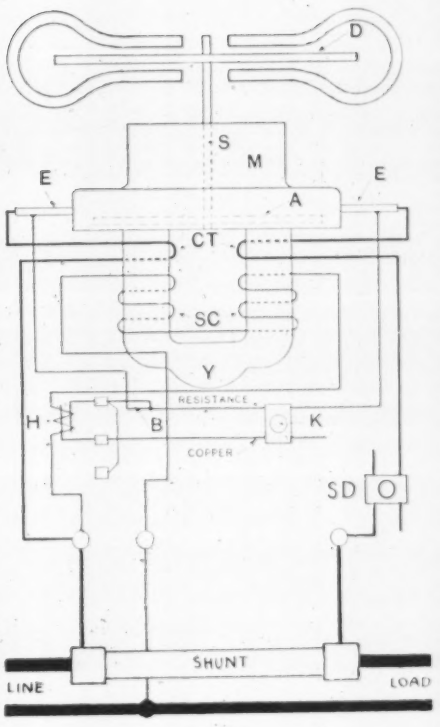


Fig. 42-14

The mercury motor meter is produced in America by the Sangamo Electric Company, and in England by several manufacturers, notably the Chamberlain & Hookham Co. and the Ferranti Co. The mechanism of a Sangamo meter is shown in Fig. 42-12; its parts in Fig. 42-13, and its circuit in Fig. 42-14. The disk *A* and the body of mercury in which it is immersed are enclosed in a molded cell having electrodes *E* at diametrically opposite points, through which the current is carried into and out of the disk. An electromagnet structure provides the axial field and is excited from the voltage of the system, these coils being represented by light lines. The heavy lines *CT* are compounding turns to augment speed on heavy loads when fluid friction becomes considerable. Solid friction in this type of meter is extremely low; it is adequately compensated for by a small current passed through the disk from a thermocouple heated by a resistor *H* in series with the voltage circuit, the value of this current being readily adjusted by shifting block *K*. Fig. 42-14 is the circuit of a *shunted* Sangamo meter for ratings above 10 amperes, and shows the adjustment *SD* for exactly proportioning the resistances of the current circuit to that of the individual shunt under individual line conditions.

9. Ampere-hour Meters

The use of the ampere-hour meter is limited almost entirely to electrolytic processes, electric vehicles and other direct-current installations embodying storage batteries. Some use has been made of it on trolley cars with a view to checking efficiency of operation. The first alternating-current meters were ampere-hour meters; but the measurement of a.-c. ampere-hours is now almost unknown except in special laboratory applications. The design and construction of an a.-c. ampere-hour meter are more difficult than for a d.-c. meter. The a.-c. metering element develops a torque inherently proportional to the square of the current, requiring intricate retarding devices in order to produce a straight line relationship between current and speed. On the other hand, by deriving the field of a d.-c. ampere-hour meter from a permanent magnet, the driving torque may be made directly proportional to the current flowing.

The earliest meters for billing users of electric current were based on the electrochemical principle and measured on an ampere-hour basis. When expertly used they were capable of great precision, but they have long since become obsolete and have been replaced for billing purposes by watthour meters. The only representative ampere-hour meter now manufactured in this country is the Sangamo mercury-motor type which corresponds closely to the watthour meter described above, except that the potential magnet is replaced by a permanent magnet.

INSTRUMENTS BOOK SHELF

Electric Power Metering. By Archer E. Knowlton. McGraw-Hill Book Company, Inc., New York. Cloth, 5½x8 inches, 340 pages. Price $4.00.

There are many books on electrical *measurements*, but this is the first which claims to be exclusively on *metering*. Volumes have been written on watthour meters, their design, uses and maintenance; but mostly from the standpoint of the meter superintendent in the utility laboratory, or of the manufacturer. It is refreshing to have the Professor step down from his platform and go behind the board with the meter man, giving him the benefit of a wide perspective, and at the same time bringing to the student a knowledge of problems encountered in the field. this book is an outgrowth of courses for electrical meter engineers conducted by the author at Yale University in cooperation with NELA meter committees and it incorporates also the author's experience gained in conducting the standardizing and supervisory laboratory of the Connecticut Public Utilities Commission.

As the author assumes the fundamentals of electrical measurement to be known to his reader and also credits him with a working knowledge of engineering mathematics, he is able to launch into his subject abruptly without elementary chapters. We find wattmeter connections discussed on the third page and elusive sources of error in the first chapter. Here appears also a tabulation of the principal mechanical and electrical characteristics of 35 well-known types of indicating instruments.

The subject of instrument transformers is treated in a clear and concise manner, explaining possible errors and hazards in their use and presenting data for corrections in both tabular and graphic form. In leading up to a full understanding of the circuits upon which power measurements may be required, polyphase systems appear, first in a somewhat elementary treatment; and the reader's mind is refreshed in those aspects of polyphase currents necessary to a clear understanding of their measurement. The concepts of *symmetrical components* and *unbalance factor* being to some extent newcomers in the field of measurement, few writers have heretofore had the opportunity to teach their significance as essentials of the general subject of polyphase systems. By a novel method of reasoning the author has introduced new material along with the more familiar magnitudes, so that engineers of the older school of electrical measurement, along with adepts in the most modern practices of thought, may approach the subject with little fear of confusion. As a basis for logical measurement of power in multi-conductor circuits, Blondel's theorem is elucidated, and there are shown a number of special cases, such as three-wire single-phase and balanced polyphase systems, where the general requirements of the theorem may be waived in favor of simpler methods.

The historical evolution of the watthour meter occupies a brief but complete chapter. For fuller information the reader is referred to a bibliography of articles appearing (mostly in the British press) during the past fifty years. The author handles the engineering features of both a-c. and d-c. watthour meters in great detail, every conceivable factor affecting performance being discussed in full, thus providing an introduction to an analytical treatment of all modern and practicable methods of compensation for possible errors.

To the reader who has not been in close touch with the art of metering for the past decade the recorded advance in the technique of watthour meter testing is striking. Modern methods of making meter tests are shown, together with circuits for testing and methods for regulating and determin-

ing current, voltage, power and phase relationship in test circuits.

As is to be expected in a treatise on power metering, the polyphase meter receives special consideration, stress being laid on those adjustments and compensations which differentiate it from the single-phase form; on the choice and connections of instrument transformers for use with polyphase meters, together with the most concise methods of incorporating in the ultimate measurement the ratios and ratio *errors* introduced in an earlier chapter; and on precautions to be observed in regard to wiring, grounding, fusing and interconnection of secondary circuits. The important subject of erroneous connections in polyphase metering circuits is fully analyzed, four practical methods of verifying and correcting connections under balanced load conditions being described.

The power factor of polyphase loads is treated logically, the author wisely avoiding controversy and adopting the A.I.E.E. "Second Definition" of 1920, and basing his measurements and computations on this concept. Generally accepted methods of reactive metering and power factor determination are shown, a precise analysis of the several practices being reserved for a subsequent chapter. In the use of the term "average power factor," as determined from the combined registrations of a watthour meter and a reactive meter, the reader is reminded that this is not necessarily a true average of the successive instantaneous values of power factor.

A chapter devoted to the practical application of Fortescue's system of symmetrical components provides a comprehensive treatment of unbalanced circuits. With this as a basis the matter of accuracy of reactive metering is reopened, and the possible errors associated with the several methods of performing such measurement analyzed and exhibited in the form of a tabulation. A full understanding of this section demands a study of an article by the author in the *Electrical World* for 1923; and even with this before him the reviewer found difficulty in coördinating the data so presented. The impression obtained from a digest of the whole section on reactive metering is that the possible errors due to voltage unbalance have been given undue prominence, while at the same time a search fails to reveal any reference to equally probable errors due to wave-form distortion.

As a suggestion of a solution to the difficulties in reactive metering the phase sequence networks of Evans are outlined, and some possible applications discussed; but as a solution more fundamental in its nature the author recommends the direct determination of the magnitude *volt-amperes* in the circuit. Several forms of volt-ampere meters and volt-ampere-hour meters are described, and their performances compared. In the chapter on demand metering there are described practically all types of demand meters in present or recent use, with a discussion of their respective performances and inherent discrepancies. The interrelated subjects of totalizing and telemetering are included in a single chapter, several modern methods applicable to the remote measurement and summation of power values being shown in detail.

The book closes with a 9-page appendix, "Instrument Characteristics and Performance," compiled from several sources. This material, applying to *instruments* rather than *meters* and hence not consistently classifiable elsewhere in the work, nevertheless pertains to the general subject. It covers features of standardization and mechanical design and lays considerable stress on damping. Thus, in a few paragraphs there are brought out facts essential to the best operation of indicating instruments, enabling the reader to broaden his perspective of the field of electrical measurement in its relation to the art of metering. The text of the book is amplified by 12 tabulations and by 215 cuts including many original diagrams and several halftones illustrative of outstanding types of meters and meter parts.

This volume differs from most works on electrical measurement in that it is instructive rather than descriptive. Many chapters are followed by groups

10. Induction-type Meters

Energy measurement on a.-c. systems is now performed almost entirely by the induction type watthour meter, which combines extreme mechanical simplicity with remarkable electrical accuracy. The principle of the induction type instrument was briefly discussed in the March 1934 article, the treatment there being applied to the "rotating field," as produced by interacting fluxes having displacement in both position and time-phase. The principle as applied in the watthour meter is basically the same but the field produced may here be more correctly termed a *traveling* or *shifting* field. With this concept in view the operation will be understood by reference to Fig. 42-15 which represents the electromagnetic system of one of the earlier Westinghouse meters but contains the elements to be found in the driving element of practically any form of induction-type meter. Two more or less independent magnetic circuits are arranged to superimpose their fields on a conducting disk, a portion of which occupies an air gap common to both. The magnetic circuit carries two distinct windings, one of a few turns connected in series with the circuit to be metered, and one of many turns, therefore highly inductive, connected across the circuit. When the current in the metered circuit is in phase with the voltage (100% power factor) the currents in the two windings are displaced almost exactly 90 degrees in relation to each other. The principal part of the flux produced by the potential coil circulates in the almost complete magnetic circuit associated with that coil, but a portion of it is diverted and crosses the main air gap to the tips of the poles *B* and *D*. The polar projections associated with the two windings are so spaced along the air gap that the interaction of their respective fluxes produces a shifting field in the gap, much as though a magnet were being continuously moved along the space. The strength of this shifting field with 90 degrees' phase difference between the currents in the two coils (100% power factor in the metered circuit) is proportional to the product of the current and voltage in the metered circuit. It will be seen that at any other power factor the strength of the shifting field is also proportional to the power factor of the circuit, so that the strength of the rotating field is proportional to the product of the volts, amperes and power factor, and therefore to the actual power.

The moving element, a light non-magnetic metal disk supported on a vertical spindle and projecting into the air gap, acts like the short-circuited rotor of an induction motor, currents being induced in it and combining with the shifting field to produce a continuous torque proportional to the power in the circuit. To make this torque proportional to the power at all values of power factor it is essential that there be maintained a true quadrature relation between the potential flux and the applied voltage. This is obtained by a short-circuited "lagging coil" surrounding the pole tip C of the potential system. A current is induced in this coil and in turn sets up a flux which com-

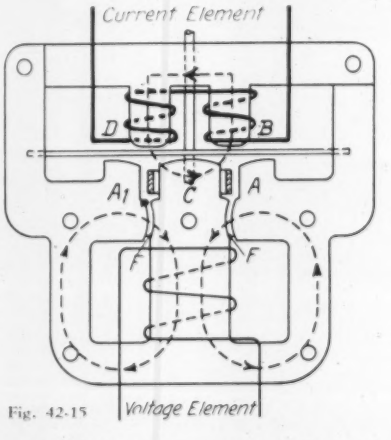


Fig. 42-15

The shifting nature of the field can be shown by comparison of Fig. 42-15 with the tabulation in Fig. 42-16. The dotted lines show the main paths of the magnetic flux produced by the two windings, only a portion of the potential flux being diverted across the main gap and through the disk. Denoting the several pole tips by the letters shown, Fig. 42-16 represents the field relations at each quarter-cycle. Thus, at one instant, as the instantaneous value of the current in the potential coil is a

	A_1	D	C	B	A
START	N	0	S	0	N
¼ CYCLE	0	N	0	S	0
½ CYCLE	S	0	N	0	S
¾ CYCLE	0	S	0	N	0
1 CYCLE	N	0	S	0	N

Fig. 42-16

maximum, the poles A, C and A_1 of the potential magnetic system are maximum north, south and north respectively, while the value of the series flux is zero. A quarter-cycle later the current in the potential winding passes through its zero value and that in the series coils reaches a maximum, the pole tips *B* and *D* now being south and north respectively. At the next quarter-cycle conditions are reversed from what they were at the beginning and at the succeeding quarter-cycle they are opposite to what they were at the end of the first interval. It will be observed that both the north and south poles move progressively in the direction from A_1 to A, giving a shifting field in the air-gap

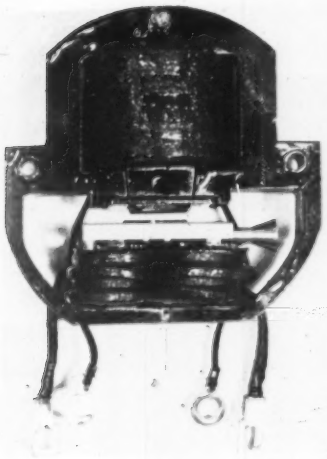


Fig. 42-17

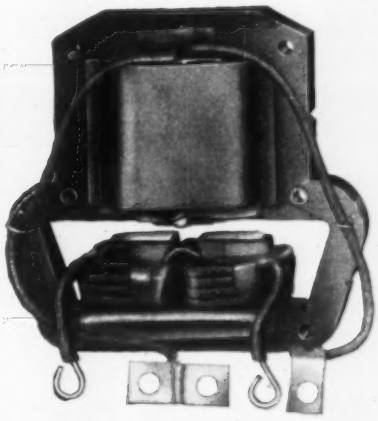
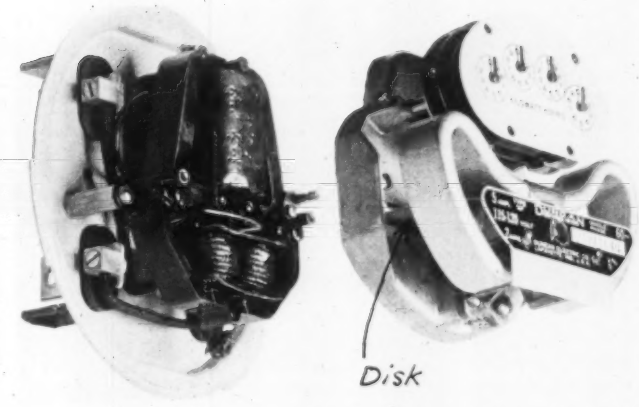


Fig. 42-18

Fig. 42-19



bines with the potential flux to produce a condition of true quadrature in the portion threading the meter disk.

The control of the speed of a watthour meter has been explained in Section 3. In the induction type of meter the eddy-current retarding torque is applied to the *same disk* as forms a part of the motor element. This fact of having one armature perform a dual function has minimized the weight of the moving assembly and it has made its bearing friction almost negligible as compared with that of heavier types.

Though total friction in the induction-type meter is much less than in the commutating and mercury types, it requires compensation. This is effected by slightly distorting the potential flux and introducing a small out-of-phase component, so as to maintain a constant forward torque irrespective of current in the current coils. In some forms this is accomplished by having copper loops adjustable in the curved slots shown in the potential iron of Fig. 42-15. Many modern meters accomplish this adjustment by a movable copper plate in the air gap beside the disk.

The driving element, shown schematically in Fig. 42-15, is manufactured as one assembly, separable from the rest of the meter. A Westinghouse driving element complete is shown in Fig. 42-17; and a General Electric element in Fig. 42-18. Worthy of mention for interchangeability and ease of dismounting and assembling is the Duncan "Type MF-S" meter: Fig. 42-19 shows (at left) its base plate, supporting the driving element, and (at right) the frame carrying the moving element, retarding magnets and register. This particular model of Duncan induction meter is the new "plug-in type"—a form now made by all meter manufacturers, and for which there is a fast-growing demand.

11. Sources of Error in Induction Meters

In the design of the induction type of watthour meter as described in the preceding section, there are several inherent sources of error; and much attention has been given to the minimization of inaccuracies resulting therefrom. The principal sources of error can here be treated only in the briefest manner, with mere mention of the basic cause of each and of the means adopted for its minimization.

(1) *Voltage Error.* A meter adjusted to read correctly at one value of voltage may have an error at another value. This may be traced principally

of pertinent problems taken mostly from actual practice, and a liberal use of cross-references makes the work particularly suited to the use of the student. The material, however, is far from elementary. It treats of the problems of metering with a maturity and authority fully commensurate with the economic importance of the transfer of electrical power. Results of studies in the field of power metering are brought together as never before in a uniform light and a correlated manner which make the book deserve a place in the libraries of all engineers and executives having jurisdiction over the commercial measurement of electric power loads.

—PERRY A. BORDEN (4-23)-B-

Automatic Protection of A.-C. Circuits. By G. W. Stevens. Instruments Publishing Company, Pittsburgh, 1935. Cloth, 5½x8½ inches, 293 pages. Price $5.00.

This book reflects the amazing development in large-scale power transmission which has taken place in Great Britain during the past decade under the Government sponsored "Grid" system. The subject matter falls into five main divisions: (1) protective transformers, (2) the interconnection of these transformers to form protective circuits, (3) relays, (4) modern methods of protecting electrical apparatus, and (5) the testing of relays and protective circuits.

Characteristics of instrument transformers are treated principally as bearing on protective systems rather than on measurement. Special attention is therefore given to performance under overload conditions, pointing out the extent to which maintenance of characteristics under these conditions is of greater importance than high intrinsic accuracy. The interconnection of these transformers is discussed in great detail, with particular reference to the effects of relay impedance.

The subject of symmetrical components is comprehensively considered in both its three-phase and two-phase aspects. This section of the book may be studied with profit by those interested in the general subject of electrical measurement and metering as well as by the relay engineer. Relays as electromechanical units are classified and fully described, both as to their actuating elements and their contact arrangements, though little attention is given to the actual mechanical features of individual makes and types of relays. This chapter closes with a digest of the British Standard Requirements for Protective Relays.

Under the heading of The Protection of Electrical Machinery are treated rotating machinery and transformers and a long chapter is devoted to the protection of cables and lines. Detailed attention is given to special cables and windings developed for the express purpose of facilitating the use of protective devices. There appears a full discussion of the testing and maintenance of protective apparatus; and the only reference in the book to wave-form effects is found in connection with references to possible distortion due to protective equipment. Considering the known phenomena of wave-form distortion in certain types of current transformers when heavily overloaded, it would seem that in not mentioning this important matter the author has been guilty of an unfortunate omission.

The book closes with two appendices, one a bibliography of twelve references (ten of them to British authorities) and the other a glossary of terms used in British protective practice. The references cited, while authoritative, give but a scant perspective of the field and the value of the book as a work of universal interest would be enhanced were recognition given to the mass of research and development which has been carried out on this side of the Atlantic. The volume is liberally illustrated with diagrams and line drawings; the material is logically presented in a lucid manner; and the whole provides a concise treatment of a subject upon which it has heretofore been difficult to collect comprehensive data without extensive reading in diversified publications.

—PERRY A. BORDEN (4-23)-B-

MANUFACTURERS' NEW LITERATURE

In this department we list each month the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.

C53 **Taylor Rochester.** The Fall 1934 issue of this house organ contains the following articles: Early Weather Notes; Long Range Weather Forecasting; Control of Moisture in Kiln Drying Lumber; Is Normal Weather a Myth?; Soil Temperatures in the U. S. Taylor Instrument Cos., Rochester, N. Y.

C54 **Time Switches.** Bulletin 228 describes Stromberg-Paragon Time Switches and Time Controls for automatically turning electric circuits "on" and "off" at predetermined times. Stromberg Electric Co., 223 W. Erie St., Chicago, Ill.

C55 **Golden Jubilee Jena Glass Works.** Fish-Schurman Corp., 230 E. 45 St., New York City, have available a leaflet on the Golden Jubilee of the above.

C56 **Diamo-Brinell Hardness Testing Machine.** Leaflet describes this new hardness testing machine which uses a pyramid shaped diamond indenter. Pittsburgh Instrument & Machine Co., 1026 Reedsdale St., Pittsburgh, Pa.

C57 **Bakelite Review.** The January 1935 issue of this house organ illustrates the use of Bakelite in the following instruments: barometer, hygrometer, camera, pH tester and case for surgical instruments. Bakelite Corp., 247 Park Ave., New York City.

C58 **Iso-elastic.** Leaflet contains information on this spring material reprinted from Product Engineering. John Chatillon & Sons, 85 Cliff St., New York City.

C59 **Furnace Pressure Control.** Leaflet illustrates the control and lists some of the applications. Leeds & Northrup Co., 1901 Stenton Ave., Philadelphia, Pa.

C60 **Tank-O-Meter.** Leaflet describes an instrument for indicating the contents of a tank any distance away. Uehling Instrument Co., Paterson, N. J.

C61 **Electric Contact Draft Gages.** Bulletin 2018 covers the new line of Hays "Draftrol" electric contact gages for indicating and controlling draft, pressure and differential draft or pressure. Hays Corp., Michigan City, Ind.

C62 **Hydrogen Ion Testing.** List No. 3 describes a method of pH testing which avoids all difficulties met with in testing highly colored, turbid, viscous, semi-solid mediums. Pfaltz & Bauer, Inc., 300 Pearl St., New York City.

C63 **Inspectron Relay.** Leaflet describes the application of this relay to inspection devices in conjunction with electronic tubes. Electronic Inspection Laboratories, 942 Prospect Ave., Cleveland, Ohio.

C64 **General Radio Experimenter.** The January issue contains the following articles: Monitoring of Broadcasting Stations, Variac applications in photography, Direct Reading Variable Inductors. General Radio Co., 30 State St., Cambridge, Mass.

C65 **Glass Thickness Viewer.** Publication 218/2 illustrates an instrument intended for the measurement of the thickness of glass sheet, plate, blown glassware, tubes, etc. Adam Hilger, Ltd., London, N.W.1, England.

C66 **Filter Paper.** Bulletin lists various grades of Munktells filter paper and characteristics of these papers. Prices are also included. E. H. Sargent & Co., 155 E. Superior St., Chicago, Ill.

C67 **Immersion Pyrometer.** Bulletin 50 covers a self-contained instrument for use in measuring the temperatures of Molten brass, bronze and aluminum. Pyrometer Instrument Company, 103 Lafayette St., New York City.

C68 **Humidistats.** Bulletin K is a condensed catalogue of air-conditioning products of Julien P. Friez & Sons, Inc., Baltimore, Maryland.

(*Continued on page 80*)

to the damping effect of the potential flux on the disk. The disk is damped not only by the permanent magnets but by any flux, whether unidirectional or alternating, which may pass through it. A change in the total value of flux from the potential iron may therefore change the damping to an extent sufficient to affect the operating characteristics of the meter. The general tendency would thus be for the meter to run slow on high voltage. The effect of this source of error is minimized by designing meters to have a characteristically slow disk rotation; and by careful design of the magnetic circuit it is possible to make use of the varying saturation intensities of different portions of the iron to compensate further for such voltage errors as may tend to appear.

(2) *Overload Error.* In a manner similar to that of the potential flux, the magnetic field from the current element tends to increase the damping effect and retard the meter disk as the current value is increased. Rapid increases in the magnitude of domestic loads in the past decade have made it particularly important that meters maintain their accuracy over a wide range of current values; and the older types of meters have been found to be notably deficient in this regard. All modern designs of induction meters have compensation, usually in the form of a magnetic shunt which becomes saturated at high current values, diverting a greater proportion of the flux to aid the driving torque and thus offset the abnormal damping effect.

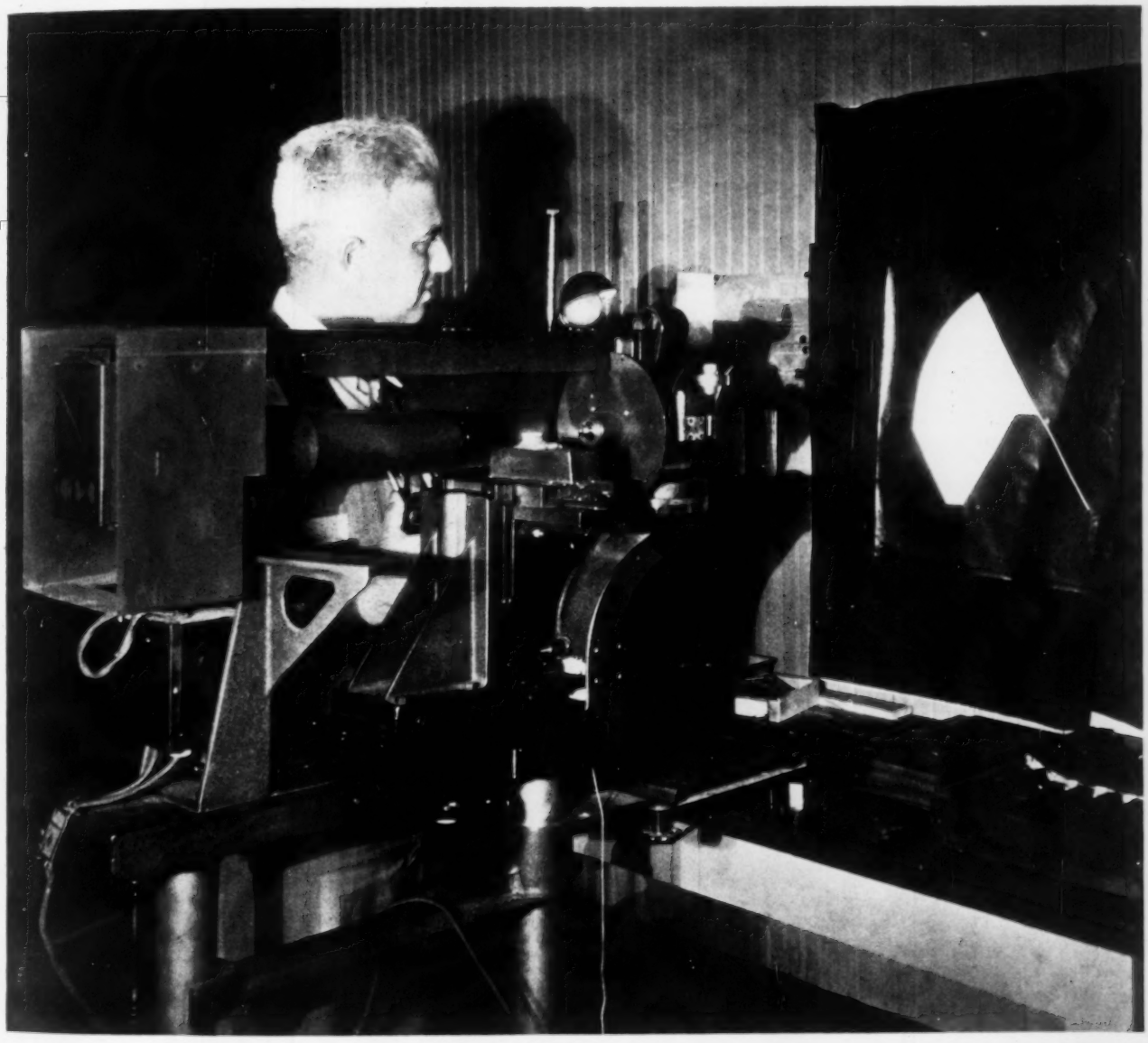
(3) *Power Factor Error.* As has been pointed out, it is essential in order that the speed of a meter shall be proportional to the power at all values of power factor, that the potential flux maintain a state of true quadrature with the applied voltage. The manner of effecting this by means of a "lagging coil" has been explained in the preceding section.

(4) *Frequency Error.* The lagging coil provides a quadrature relation in the potential flux for only one value of frequency. In some of the earlier designs there was provided an adjustment whereby the true quadrature relation might be obtained for any one of several frequencies; but the widespread standardization of modern power systems to a few definite frequency values has rendered this practically superfluous; so that the accuracy of a meter at any frequency other than that for which it is designed and adjusted may generally be ignored.

(5) *Wave-form Error.* Errors due to distortion of wave form are closely associated with frequency errors. A departure from a true sine wave may be treated as the superimposition of a higher frequency on the system, so that though a complete analysis of wave form effects becomes an intricate problem, the general result is akin to that of an increase of frequency, and in well designed modern meters on commercial systems may generally be neglected. The only perceptible tendency under distorted wave forms where the distortion is not extreme is for the meter to run slightly fast on lagging power factor.

(6) *Temperature Errors.* Varying temperature conditions may be responsible for two types of error in induction meters. Changes in the electrical resistance have little effect on the accuracy; and variations in the resistance of the disk affect the retarding torque to the same extent as the driving torque, and are thus self-compensating. The principal source of temperature error at unity power factor is found to lie in changes in the damping magnets. In modern meters this is compensated for either by the use of a temperature sensitive material (bimetallic strip, etc.) arranged to shift a magnet or a part of the magnetic system and thus to vary the retarding torque, or else by the use of a magnetic shunt made of material varying its permeability with temperature and diverting more or less of the main flux from the meter disk. By varying the electrical resistance of the potential lagging coil, temperature changes tend to introduce at low power factors errors which may be more serious than those at high power factors. There have been developed several methods of compensating for this source of error, one of the most effective being to "over-lag" the potential iron with a coil having a relatively low temperature coefficient, and then to provide on the pole tips of the current coil a lagging by means of a coil or ring having a relatively high coefficient. Thus, as the potential flux tends to be thrown out of phase by resistance changes in the potential lagging coil, the current flux is shifted through an angle sufficient to compensate for the change. It might be said "why not make the lagging coil of material having a zero temperature coefficient?" It is to be remembered that all such alloys have a high specific resistance, so that a coil of such material having sufficient conductivity to provide the necessary lagging current could not be accommodated in the limited space available. Consequently in this type of lagging use is made of a metal having an intermediate characteristic, such as phosphor bronze.

INSPECTION and TESTING



CONTOUR PROJECTOR IN GAGE DEP'T OF PRATT & WHITNEY CO., HARTFORD, CONN.

(Courtesy Bausch & Lomb Optical Co.)

Materials Testing Machines

An Account of Their Development, with Special Reference to the Tension-Compression-Transverse Group

By C. H. GIBBONS*

PART FIVE

In 1872 a commission of American engineers memorialized Congress and urged on the United States Government the necessity for complete materials strength data on American iron and steel. The Congress appointed a board consisting of Lt. Col. T. T. S. Laidley, U. S. A., President; Commander L. A. Beardslee, U. S. N.; Lt. Col. Q. A. Gilmore, U. S. A.; David Smith, U. S. N., Chief Engineer; W. Sooy Smith, Civil Engineer; Alexander L. Holley, Civil Engineer, and R. H. Thurston, Civil Engineer, Secretary, to make investigation and, since no adequate materials testing machine was available, appropriated fund for the construction of such a testing machine. After investigation, the board, on July 19, 1875, contracted with A. H. Emery, of Chicopee Falls, Massachusetts, for the construction of a precision testing machine of 800,000 lbs. capacity in tension, and 1,000,000 lbs. in compression and large enough to accept specimens up to 30 feet in length. It was to be completed in five months. The specifications were unheard of in their rigidity. For example, after a test under full load, it was necessary that without adjustment, a test requiring a very light load be made with precision. How well this particular requirement was met will appear!

This machine, long called "the United States Testing Machine," was built by Ames Manufacturing Company, of Chicopee Falls, Mass., under the personal direction of Mr. Emery. Castings were made by the South Boston Iron Works and steel and iron forgings by the Nashua Iron & Steel Works. The total weight is about 175,000 lbs. and the purchase price was $31,500.00. Erection, foundations, heating and a traveling crane increased the cost to the Government to $43,004.52. It is said that the machine cost the contractor no less than twice the amount paid by the Government. Colonel Laidley, president of the board, said in a report, June 30, 1879, "The machine is more perfect than we had any right to expect from the terms of the contract. The board is of the opinion that the Government should, under the circumstances, come to the relief of Mr. Emery and not allow him to suffer so severely for his unusual devotion to its interest."

This famous Emery Testing Machine was installed at the Watertown Arsenal, Watertown, Mass., early in 1879 and was accepted for the Government by Colonel Laidley on February 8, 1879.[61] It stands there today after more than half a century of continuous and satisfactory service, one of the largest and most precise testing machines in the world, and a monument to the mechanical genius of Mr. Emery. Fig. 26 gives an idea of its appearance. The ram is 20" in diameter and has a stroke of 24". The cylinder is lined with copper and the ram is double cup leather packed. Sperm oil was used for the hydraulic fluid. The 8½" diameter screws were true in diameter within 1/1,000" and were threaded with a truncated thread, two per inch. They are 50" apart, allowing ample access to the specimen under test. Center line of machine is 47" above floor level. Overall multiplication ratio is 420,000 to 1.[61-62]

A steam pump having 1½" diameter and ⅞" diameter hydraulic plungers, double acting, furnished sperm oil under pressure to a special double accumulator having two rams, concentric with each other, one being 10" in diameter and one being 5½" in diameter. Brick and masonry piers in three sections furnished the accumulator weight and the arrangement was such that pressures varying from 380 to 3,400 lbs./in.² were available.[62]

The main cylinder ram (or piston, since it is double acting) is forged from one piece, the head being 20"

*Baldwin Southwark Corp., Philadelphia, Pa.

[61] *Engineering, London*, Vol. 27, Mar. 28, 1879, page 267.

[62] A most comprehensive and detailed report, together with numerous line drawings may be found in the Annual Report of the Chief of Ordnance, U. S. Army, 1883, Pages 283, et seq.

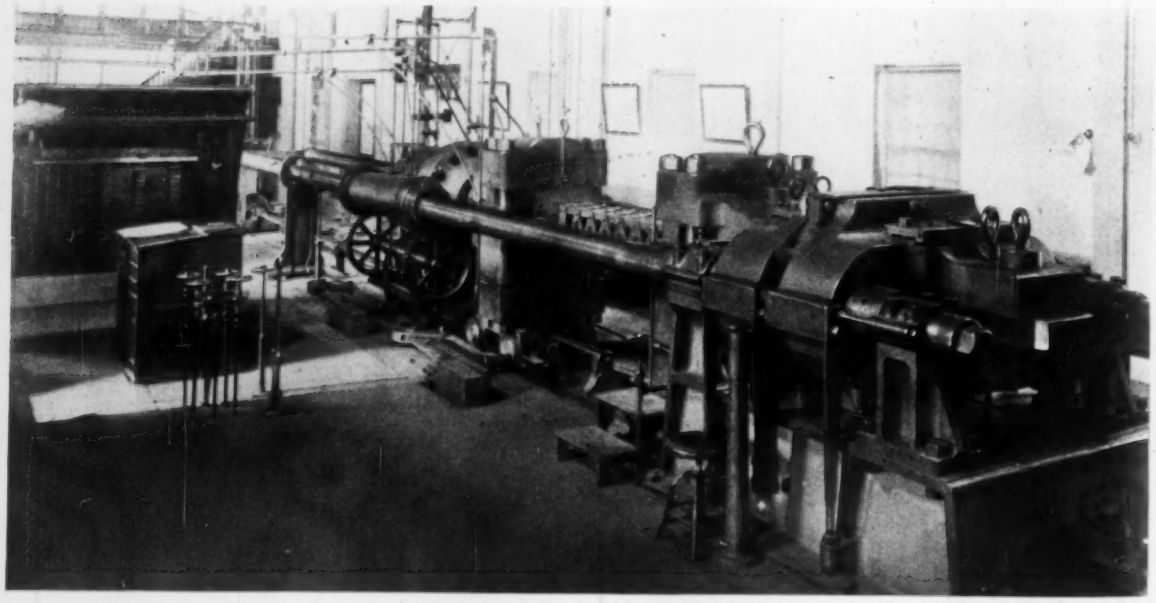


Fig. 26. The famous Emery testing machine at the Watertown, Massachusetts, arsenal, 1879.

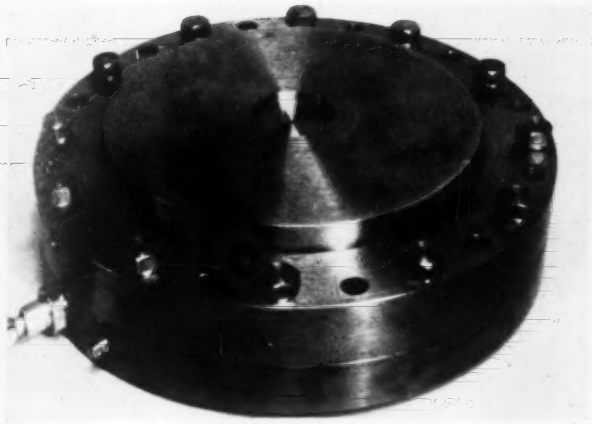


Fig. 27. An Emery weighing capsule.

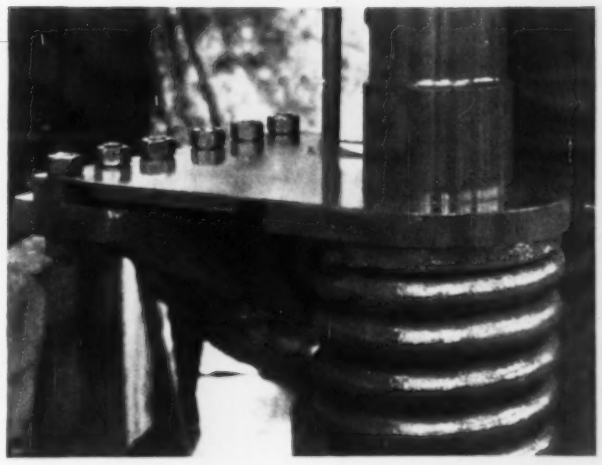


Fig. 28. Flexure plate construction of a Southwark-Emery testing machine.

in diameter and the piston rod being 10″ in diameter. Thus the actual loads available are of the order of 800,000 lbs. in tension and 1,000,000 lbs. in compression. Compression specimens up to 30 feet length and width not exceeding 30″, tension specimens up to 37 feet, and by special arrangement and with a somewhat limited range, tension specimens up to 45 feet in length may be accommodated.[63] Testing speeds can be varied from 1 inch per minute to 1 30,000″ per minute.

This famous testing machine has at least two outstanding unique features. One of these is the use of the hydraulic support, which is essentially a shallow cylinder having a loose fitting piston and a metal diaphragm so arranged that the load on the specimen must pass through a thin film of liquid trapped between the piston (and diaphragm) and the bottom of the cylinder. See Fig. 27. An accurate measurement of the hydraulic pressure in the support, then, gives as a result of a previous precise calibration, the actual load on the specimen entirely independently of the pressure in the main cylinder or of the packing friction or of any of the usual losses and inaccuracies. This was, in association with the auxiliary hydraulic support in the weighing scale, a combination of the idea of Thomasset with that of Maillard—a large hydraulic support accepting the full load from the specimen under test and in series en route to the weighing scale another hydraulic support of smaller dimensions. In effect, this introduction of the auxiliary support was the introduction of a hydraulic lever of large ratio—as Thomasset had introduced a mechanical lever—without any of the disadvantages of knife-edges or of very short lever arms. The other unique feature was the use of flexure plates in place of knife-edges throughout the entire mechanism wherever small rotational motions were necessary. (Fig. 28.) This latter idea was not unknown, having been suggested by Weber at Göttingen in 1841 and by M. Taurines in 1867,[64] but careful search fails to reveal that the idea had ever been applied.

In the Watertown machine are four hydraulic supports arranged in parallel and each accepting a share of the total load.[64] Pressure from these supports is taken by four auxiliary supports of essentially the same construction as each of the four first mentioned, but of smaller dimensions. In effect, this is the introduction of an hydraulic lever of fairly large ratio and entirely without frictional losses. A lever system employing flexure plates (Fig. 29) completes the weighing system with an overall ratio of 420,000 to 1; that is, one pound in the scale balances 420,000 lbs. in the machine, and conversely 1 10″ movement of the scale produces 1 4,200,000″ movement of the load. The weights for use with the scale are of brass to assure permanence of weight. Later machines used gold-plated cast iron weights.

The flexure plates in the scale vary from 0.004″ to 0.060″ in thickness and the unsupported length is from 0.1″ to 0.2″. Some are in compression and some are in tension. Loads are held to about 50,000 lbs. in.[64]

As a part of the acceptance test, a forged link of hard wrought iron was broken at 722,800 lbs. Diameter before test was 5.04″ and after test was 4.98″. At once and without adjustment, a horse-hair 0.007″ in diameter was slowly strained and after stretching 30%, was broken at one pound and the load adequately indicated by the scale! Subsequent tests on bits of the horse-hair by dead weights broke at one pound also![64] Masses of

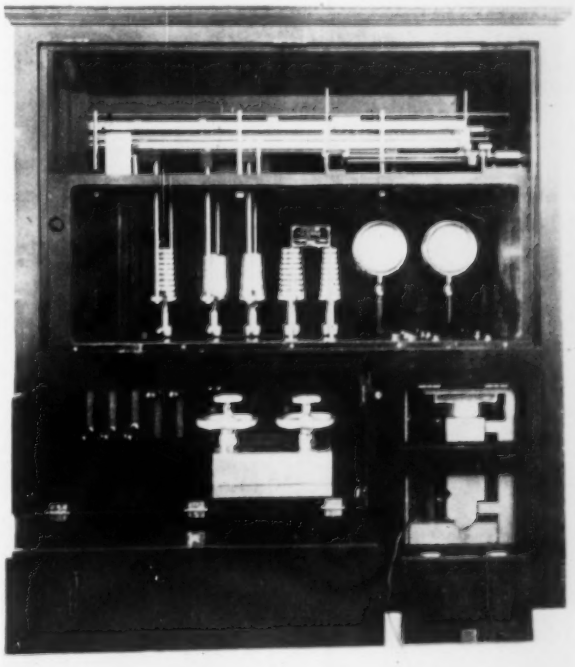


Fig. 29. An Emery weighing scale. (Courtesy National Bureau of Standards.)

[63] *The Engineer*, London, Vol. 65, Jan. 20, 1888, page 54.
[64] Henry Towne. *Engineering*, London, Vol. 45, May 18, 1888, page 481.

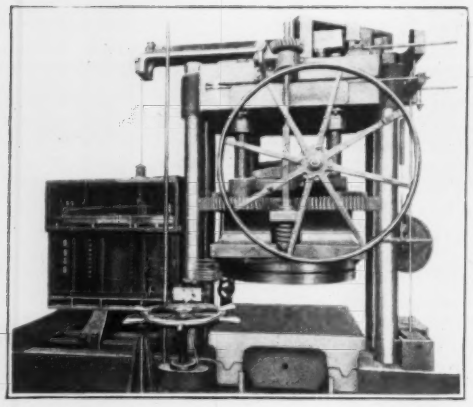


Fig. 30. An Emery capsule calibrating machine.

metal were loaded to 1,000,000 lbs., alternately with eggs and with nut shells, and in all cases the machine operated with equal sensitivity.

Gages were provided both for the pressure in the straining cylinder and for the pressure in the grip-closing cylinders. These were unique in that they, too, were essentially hydraulic supports, the load in an auxiliary cylinder in the gage being made to operate a hand moving over a dial face instead of a reading by balancing a lever. Moreover, the internal construction contained levers with flexure plates, the necessary resistance being supplied by stiff leaf springs, and the hand being returned to zero by a light hair-spring. Zero adjustment was also provided.[62]

As a further test of the great accuracy of the machine and before final acceptance by the Government, it was arranged as a balance; that is, a weight measuring device. In seven weighings of 100 lbs. the greatest observed difference of reading was 1 1,750,000 of the load (just over 6 grains) and of nine weighings of 200 lbs., 1 2,350,000 of the load (just under 10 grains).[36]

The late W. C. Unwin, then Professor of Engineering, Central Technical College, of the City and Guilds of London, later president, Institute Civil Engineers, and president, Institute Mechanical Engineers, states,[36] "The ingenuity displayed in the mechanical arrangement of these machines, the perfection of their workmanship and delicacy and precision of their indication of the smallest differences of stress are so remarkable that it is difficult to speak of them without seeming to exaggerate." And again,[65] "The merit of the Emery Machine was that while it had been made as much more delicate and sensitive than an ordinary machine as a chemist's balance was in comparison with a grocer's scale, this result had at the same time been obtained by means which rendered the more sensitive machine less liable to injury, less liable to wear and less liable to get out of order, than the ordinary machine."

In a machine whose precision is of the order of that indicated above, calibration becomes a problem of a magnitude equal to that of the design and construction of the machine itself. In order to calibrate the hydraulic supports and weighing scale, a special machine was built (essentially that of Fig. 30). A 50-lb. weight was calibrated at the National Bureau of Standards, to within one part in 800,000. A weight of 10,000 lbs. was then made whose accuracy was of the same order, the 50-lb. weight being used as the calibrating device. The calibrating machine, as may be seen, is essentially a weighing machine using the same principles as those of the testing machine, and having a hydraulic support and a scale with auxiliary hydraulic supports, levers with flexure plate fulcra and gold-plated cast iron weights. The 10,000-lb. weight previously calibrated, as noted above, was placed on the platform and the scale balanced. The weight was removed and by means of special jacks the scale was again brought to balance. The 10,000-lb. weight was then added and the scale again balanced. This was repeated up to the full capacity of the calibrating machine, which in the case of the United States Testing Machine was 1,000,000 lbs. (compression). The four hydraulic supports intended for the machine at Watertown were then placed on the platform and connected to their own scale and, after adjustment of the calibrating scale for their weights, loads were imposed by the jacks and the testing machine scale calibrated with the master calibration scale.

The great accuracy and sensitivity of this latter calibrating device is worthy of note. There are three platforms, one of 500,000-lb. capacity, one of 5,000-lb. and one of 500-lb. That is, the lever ratios are so changed by the substitution of one platform for another, that the weight in the scale which balances 1,000 lbs. on the 500,000-lb. platform, balances 1 lb. on the 500-lb. platform. Using the 500,000-lb. platform and having it loaded to capacity, the addition of four ounces will turn the scale. Two hundred grains (1/35 lb.) laid on the 500,000-lb. platform moves 20,000 lbs. of weighing system and moves the tip of the scale beam 1/50 inch. One-half grain (1/14,000 lb.) turns the scale when using the 500-lb. platform. Provision is made for changing the sensitivity of the scale, which may be further increased over that indicated above. It becomes, of course, increasingly difficult with increasing sensitivity to balance the scale, and it is therefore necessary to balance the desire for the utmost sensitivity against convenience in service.[66]

(To be continued)

[62]Batson & Hyde, Mechanical Testing, Vol. 1, 1922.

[66]Catalog of Wm. Sellers & Co., 1895, page 364.

Relays Find Applications on Aircraft

(Continued from page 61)

the voltage regulator may maintain the upper limit satisfactorily, a lower voltage limit is best maintained by the reverse current relay.

The current limiting relay has not had as wide an adaptation in aircraft as the voltage regulator and the reverse current relay, but it serves as a protection against short circuits and in limiting the maximum current. In the event of failure of the reverse current relay there is an added safety in the presence of the current limiting relay, as it prevents high circulatory currents constituting a fire hazard. Protection against overloads might be necessary where a dynamotor is operated by the generator. In this event the current limiting relay is a necessary precaution. Should small motors appear on aircraft, it is a certainty that current limiting relays will be regarded as indispensable.

A typical arrangement of the three relays is shown in Fig. 2. They are installed on the low-voltage circuit of a typical aircraft generator. While it is not the rule to use all three of them, whatever combination is used employs the voltage regulator. The resistance units for the functioning of the voltage regulator are shown. Another important feature is the regulating device that accompanies each relay, extremely necessary, by reason of the state of vibration of the airplane as detrimental to constant setting.

The relays are built into a small compact unit known as a control box, weighing about 5 lbs. with all the relays included. This control box is provided with a cover and an effort is made to make it water-tight and protect

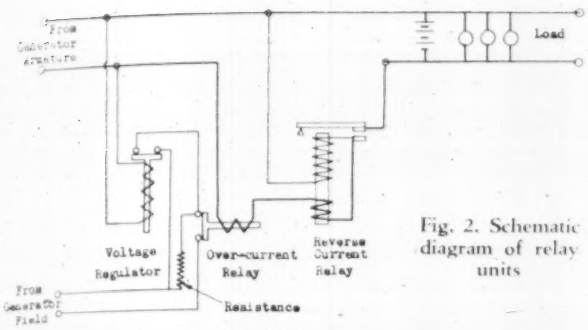


Fig. 2. Schematic diagram of relay units

the units against corrosion. Moist sea atmosphere being a particularly corrosive agent, the materials used in the construction of the relays must be highly resistant to corrosion and contacts of dissimilar metals must be carefully avoided. The contact points of the relays, in particular, should be very resistant to corrosion. Platinum-iridium alloy has been used to minimize corrosive effects on the contact points, though periodic cleaning and inspection is advisable.

The completely enclosed box not only makes for water-tightness, but also functions as a shielding for minimizing radio disturbances that emanate from the rapidly vibrating contacts of the regulator. Connections are made to the control box through standard shielded terminal housings, adaptable to standard conduit. A small condenser is sometimes placed across the vibrator contacts to minimize radiofrequency disturbances. It becomes necessary on the reception of faint radio signals to eliminate the slight disturbances originating from the operation of the generator. In this event, the field circuit of the generator is broken by some convenient method, serving to prevent the generation of electrical energy. Besides, should the relays become inoperative, a suitable method for stopping the flow of electricity is desirable.

Inasmuch as the shocks and the vibrations of the airplane may influence the operation of the relays, the control box should be so mounted as to minimize external vibration. As close regulation of voltage is imperative, care and consideration in the handling of this equipment is paramount.

In considering the electrical equipment that is to be serviced on airplanes and its importance to aviation, one can understand the need for proper regulation and control of the electrical energy by the relays.

Instrument Scale Distribution

(Continued from page 60)

[8]N. N. Ponomarev. Error Curves of Electromagnetic Measuring Instruments with More than One Range of Measurement. (In Russian.) *Elektrichestvo*, October 1930, pages 801-3. Demonstrates that the error curve of an instrument with an evenly divided scale must be a broken line and derives a relation between the error curves of the same instrument for different ranges of measurement.

[9]G. W. Stubbings. Commercial A-C. Measurements (book). Van Nostrand, N. Y., 1930. A-C. Ammeter Scales, page 73. Wattmeter Scale, page 112. Brief discussion.

1929

[10]British Electrical and Allied Industries Ass'n. Permanent-magnet Moving-coil Ammeters and Voltmeters. *Electrician*, London, Vol. 102, March 8, 1929, pages 287-289. Easily read scales, page 288. Condensed from a report by the Association.

1928

[11]G. Keinath. Die Technik Elektrischer Messgeräte (2 Vols.). Oldenbourg, München, 1928. Considerable material on scales. Vol. 1, pages 51-58, 182, 304, 307.

[12]Bubert. An Electrodynamometer with Nearly Uniform Scale. (In German.) *Elektrotechnik und Maschinenbau*, Vol. 46, April 22, 1928, pages 370-374.

1927

[13]K. Edgcumbe and F. E. J. Ockenden. Some Recent Advances in Alternating-current Measuring Instruments. *Journal of the Institution of Electrical Engineers* (London), Vol. 65, June 1927, pages 553-99. Scales, pages 554-55.

1924

[14]F. Voller. Ammeter scales and a new overload-proof ammeter. (In German.) *Elektrotechnische Zeitschrift*, Vol. 45, December 18, 1924, pages 1405-7. *Science Abstracts, Sec. B*, Vol. 28, 1925, page 194. Abstract translation.

[15]C. V. Drysdale and A. C. Jolley. Electrical Measuring Instruments (2 Vols.). Benn, London, 1924. Scale shape in soft-iron instruments, Vol. 1, page 293.

1923

[16]National Electric Light Association. Handbook for Electric meter men (4th ed.). The Edison Electric Institute, N. Y. C. Very brief discussion of scale errors, page 381, and of logarithmic scale, page 389.

[17]H. B. Brooks. Standardization of Electrical Measuring Instruments. *Transactions American Institute of Electrical Engineers*, Vol. 42, June 1923, pages 894-903. Proposed definitions (page 900) of indication range, measurement range, and scale length. Proposed requirements (page 902) as to angular length of scale division, and marking of scales.

1921

[18]A. Imhof. Methods of varying the scales of measuring instruments. (In German.) *Schweizerische Elektrotechnische Verein Bulletin*, Vol. 12, May 1921, pages 117-23. *Science Abstracts, Sec. B*, Vol. 24, 1921, pages 574-75. Abstract translation.

1920

[19]H. B. Brooks. Accuracy of Commercial Electrical Measurements. *Transactions American Institute of Electrical Engineers*, Vol. 39, Part 1, 1920, pages 495-589. Discussion of scale law, pages 501-508, including manner in which the error from bending of pointer (followed by resetting to zero with the zero adjuster) varies with the scale law.

[20]G. Keinath. Mechanical Factor of Merit and Nature of Scale of Electrical Measuring Instruments. *Zeitschrift für Feinmechtechnik*, Nos. 6, 7, 1920. Abstracted in *Elektrotechnik und Maschinenbau*, Vol. 38, Sept. 12, 1920, pages 436-437. *Science Abstracts, Sec. B*, Vol. 24, 1921, page 239.

1919

[21]A. Imhof. Influence of scale character on friction error of electrical instruments. (In German.) *Schweizerische Elektrotechnische Verein Bulletin*, Vol. 10, Sept. 1919, pages 266-69. *Science Abstracts, Sec. B*, Vol. 23, 1920, pages 84-85. Abstract translation.

1917

[22]F. M. Farmer. Electrical Measurements in Practice (book). McGraw, N. Y., 1917. Galvanometer scale, page 35.

[23]C. M. Jansky. Electrical meters (2d ed.). McGraw, N. Y., 1917. Lack of uniformity of scale, page 29. On gravity control meters, pages 29, 30, 38. On electrodynamometer instruments, pages 91, 92, 112. On induction type instruments, pages 82, 125. On permanent magnet moving-coil meters, page 45.

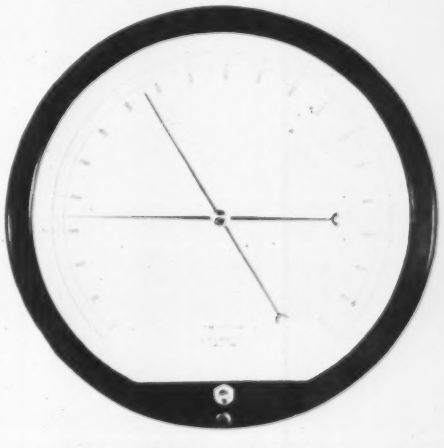
1913

[24]C. C. Paterson and others. The Use of Electrostatic Method for the Measurement of Power. *Journal of the Institution of Electrical Engineers* (London), Vol. 51, 1913, pages 294-330. Includes an appendix entitled, "On the design of scales suitable for reflecting instruments of large angular deflection, and the conditions necessary to obtain the best results." Discussions, pages 330-354.

1904

[25]Th. Bruger. On the electrodynamometer. (In German.) *Physikalische Zeitschrift*, Vol. 4, Dec. 15, 1903, pages 876-84. *Science Abstracts*, Vol. 7, 1904, page 195; Vol. 8, 1905, pages 28-29. Abstract translation. *Elektrotechnische Zeitschrift*, Vol. 25, Sept. 15, 1904, pages 832-35. Uniform scale is obtained by a trick: fixed coil bent, so that part of it actually exerts a *retarding* torque on moving coil.

PRESSURE GAUGES *of* EXTREME PRECISION



You can now obtain HEISE Bourdon Tube Pressure Indicators or Gauges made by the makers of those used on the famous Southwark-Emery Testing Machines. The first gauge used on these machines was designed by Otto W. Heise, who also designed the present improved indicator.

For extreme accuracy these gauges may be certified or calibrated at the laboratory of the A. H. Emery Co. They may be fitted with a rotating dial as supplied by the A. H. Emery Co.

If you must read pressures accurately, write us for details. We make gauges only for laboratory and test work where accuracy and reliability come first.

HEISE BOURDON TUBE LABORATORIES
275 NOBLE AVENUE BRIDGEPORT, CONN.

(Continued from page 74)

C69 **Littelfuse Products.** Catalog No. 6 covers the complete line of fuses and their varied applications in aircraft, radio, instruments, automobile, marine, laboratory, etc. Characteristics and prices are given. Littelfuse Laboratories, 4557 Ravenswood Ave., Chicago, Ill.

C70 **Counters.** Bulletin illustrates and gives data on 4 different counters for use in production. Ohmer Fare Register Co., Dayton, Ohio.

C71 **Tester for Yarn Creepage.** Reprint from *Textile Research* describes an instrument for this purpose. Irving J. Saxl, Central Falls, R. I.

C72 **Thermometers.** Bulletin L covers room thermometers, pocket thermometers, maximum and minimum thermometers, test and research thermometers, industrial thermometers. Julien P. Friez & Sons, Inc., Baltimore, Md.

C73 **Condensers.** Bulletin gives data on a number of glass condensers for laboratory use. E. H. Sargent & Co., 155 E. Superior St., Chicago, Ill.

C74 **Furnace Pressure Control.** Leaflet F-129-I gives a diagram of the L&N pressure control which shows the simplicity of the system. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

C75 **Electro-hydraulic Temperature Regulator.** Bulletin 103-12-34 describes the principle of operation and the construction of this new development of the Wilbin Instrument Co., 40 East 34th St., New York, N. Y.

C76 **Crystal Microphone.** Folder Type G gives the technical information on this crystal microphone. Turner Company, Cedar Rapids, Iowa.

C77 **Torque Dynamometers.** Leaflet describes an instrument of the hydraulic absorption type for the measurement of torque and horsepower. Torque Products Co., 875 E. Lake Forest Ave., Milwaukee, Wis.

C78 **Hot Wire Anemometer.** Mimeographed bulletin describes the hot wire anemometer, Albrecht design, for measuring smallest wind velocities. R. Fuess, Inc., 245 West 55th St., New York, N. Y.

C79 **Research Direct Pressure Engine Indicator.** Bulletin 130 describes this instrument for single pressure-time diagrams. Bulletin 134 describes additional equipment for this indicator. Commercial Engineering Labs., Woodward Ave., Detroit, Mich.

C80 **Lightning Calculators.** Form A-CE describes several models for radio design calculations. Lightning Calculator Co., Bogota, N. J.

C81 **Laboratory Microscope.** Leaflet D-187 describes and illustrates the HH microscope for elementary laboratory work. Bausch & Lomb Optical Co., Rochester, N. Y.

C82 **Thermostatic Bimetal.** Handbook on Truflex thermostatic bimetal just published by the General Plate Company, 41 Forest St., Attleboro, Mass. Here in one convenient book are summed up and presented in usable form facts about every type of bimetal now in use. This book also contains charts for rapidly calculating the proper bimetal elements to accomplish desired results.

C83 **Struthers Dunn Products.** Folder issued by Struthers Dunn, Inc., 139 North Juniper St., Philadelphia, Pa., gives a bird's eye description of their entire line of relays, timing devices, electric counters, thermostats, electric pots and ladles.

C84 **Flow Indicating Meter.** This instrument, for the indication of small gas flows in setting gas refrigerators, adjusting pilot lights, in studying leakage, etc., is covered in Bulletin 1029. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

C85 **Carbon Monoxide Alarm.** Bulletin DR1 describes in detail the M. S. A. carbon monoxide alarm, also deals with the vital matter of carbon monoxide poisoning. Mine Safety Appliances Co., Braddock Ave. & Thomas St., Pittsburgh, Pa.

C86 **Feed Water Regulator.** A 16-page bulletin entitled "Bailey Feed Water Regulators" and designated as No. 83, deals with thermo-hydraulic feed water regulators, lists distinctive features, diagrammatically illustrates the principle of operation by the thermo-hydraulic generator. Bailey Meter Co., 1050 Ivanhoe Road, Cleveland, Ohio.

NEW INSTRUMENTS

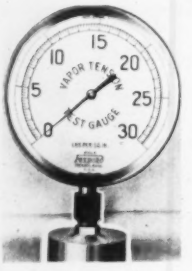
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to information Section, Instruments Publishing Company.

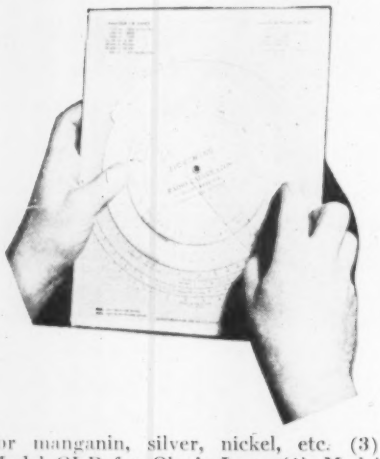
Vapor-pressure Gage

Several features seldom found in pressure gages were incorporated in the design of the Foxboro Co.'s new "Vapor Tension Test Gauge" in order to obtain the degree of accuracy necessary in vapor-pressure determination. Makers guarantee an accuracy of 0.5% of full scale at any point. Dial is rotatable over a small angle, for convenience in zero adjustment—which is said to require only a few seconds—and to avoid necessity of even touching the pointer. The Bourdon spring and all movable parts are of bronze, heavily cadmium plated. Other features are an Everdur Hair Spring, a buffed brass case with the glass held by a heavy Vellumoid gasket secured by a retaining ring. A second gasket inside the connection makes the gage completely waterproof. A square, rust-proof steel connection protects the gage from twisting strains when mounting and dismounting from the bomb.



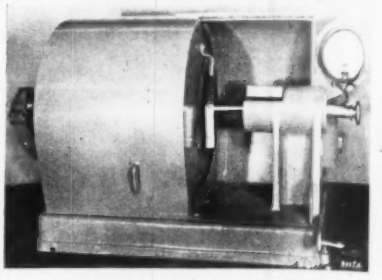
Calculators for Radio, Wire Data, etc.

Four new models, announced by Lightning Calculator Co., consist of 6-ply backs to which are fastened one or more rotatable dials and one celluloid hairline indicator. (1) Model SWP for radio: wavelength, frequency, capacity, coil diam., coil length, wire sizes and wire turns. (2) Model WDP for wire data: diam. in mils, circular mils, sq. mils, weight, resistance, turns/in., turns/in.^{2}, for manganin, silver, nickel, etc. (3) Model OLP for Ohm's Law. (4) Model LCP for resonance: capacity, inductance, reactance and frequency.



Torsion Impact Tester

In the Carpenter Torsion Impact Testing Machine (*Instruments*, Dec. 1933, page 225) the energy available for breaking the specimen was limited to approx.



500 ft.-lbs., and the size of the specimen to $\frac{1}{4}$" diam. Demand for a machine with greater stored energy, to break specimens more nearly equal in dimension to the service part, has led the Baldwin Southwark Corp. to build a larger machine with a stored energy content 10 times that of any such machine previously built. It has available at 1000 r.p.m. 50,000 ft.-lb. of energy—sufficient to test any known steel (under conditions usually obtained in such tests) in specimen diameters up to 1" diam. Its principles are identical with those of the 500 ft.-lb. machine described in our Dec. 1933 issue, but a high-grade Westinghouse magneto type tachometer has been incorporated.

Hot-wire Anemometer

For measuring air speeds below minimum points of ranges possible with other types, this Albrecht anemometer, introduced by R. Fuess, Inc., is so designed that the "velocity" scale is fairly uniform except in the upper part where it closes up. The mid-point corresponds to an air speed of 500 mm./sec. (approx. 1.64 ft./sec.) below which this new instrument seems to be most useful. It is not recommended for measuring air speeds above 15 ft./sec. *Principle.* Two of four parallel wires (D) are electrically heated while through the other pair flows a weak measuring current which effects no appreciable heating. Difference of temperature is an inverse function of ventilation, being greatest in still air. Difference of resistances—a function thereof—is measured by a double Wheatstone bridge with "precision mangin rheostats" and sensitive mirror-scale galvanometer. Extreme accuracy is said to be assured by advances in design and construction, including absolute uniformity of the four wires.

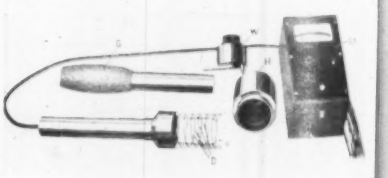
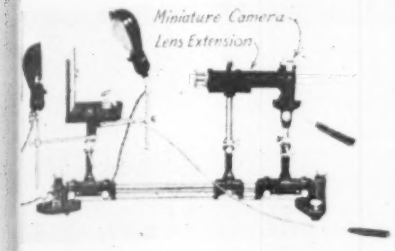


Photo-optical Bench

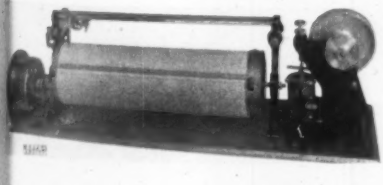
New parts and accessories are announced by R. Fuess, Inc., whereby this company's Universal Optical Bench (see *Instruments*, Sept. 1933, page 180) can be adapted to meet the most exacting requirements of photography, the user employing his own small camera (Leica, Contax, etc.), thus taking advantage of fully-corrected anastigmats and avoiding expense of special lenses. New camera support has complete tilting and panorama facilities and will take almost any size camera. Its rider has a vertical micrometer adjustment. Camera can thus be moved in three planes, and securely locked in place. Vee troughs are used singly or in pairs to support lens extension tubes. Stage has 12 × 20 cm. hori-

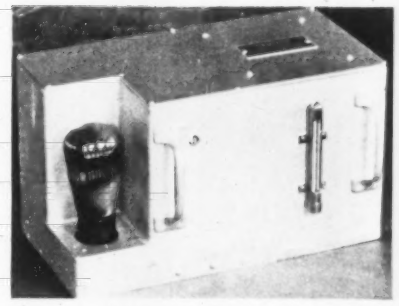


zontal surface, also two grooved posts for supporting ground glass (furnished), opal glass, opaque background, masks, etc. Beneath it are mounted two universal-motion lamp-holders. Motion of stage in direction of bed is by micrometer screw operated by flexible shaft. Numerous different set-ups are possible for ratios between 1:4 and 200:1.

Stress-Strain Recorder for Testing Machines

The consulting staff of the Baldwin-Southwark Corp. have designed a new stress-strain recorder as a substitute for the Southwark-Emery Stress-Strain Recorder and Recorder Controllers wherein a bourdon tube and associated mechanism control the rotation of the recording drum and strain controls the transverse pen motion through a Goodyear-Zeppelin (or Templin) type extensometer, as described at length in *Instruments*, April 1933, pages 90-91. The price of such a recorder is sometimes nearly equal to that of the testing machine itself. Therefore, a new "Weight Motor" type of stress-strain recorder has been brought out primarily for application to the Southwark-Heydekampf type of testing machine but by adaptation available on other types. The load movement of the recording device is directly controlled from the load indicating mechanism while the strain motion is controlled through a Goodyear-Zeppelin (or Templin) type extensometer, a sensitive relay and solenoid-actuated brake which controls the fall of a weight (whence "Weight Motor"). It is said that records can be made nearly equal in smoothness and accuracy to those of the other type. The limiting factor (shortening lengths of steps of the record) is the adventitious variation of friction in the recording unit drive.





Crystal Oscillator

A new crystal oscillator unit developed by the Westinghouse Electric & Mfg. Co. for municipal and police radio installations is said to be characterized by high frequency stability, compactness and accessibility. It consists essentially of an aluminum casting into which the crystal oven, oscillator circuit and oscillator tube are placed. The front of the oscillator contains two handles, a thermometer, a frequency adjustment and a Type 10 oscillator tube set into a depression so as not to protrude. The crystal oven is insulated with balsa wood and capable of temperature constancy to ±0.08°C. The crystal is contained in a heavy metal holder, the electrodes of which are spaced with quartz. The left section of the unit contains the oscillating circuit coils, condensers, and resistors. Frequency adjustments consist of a miniature variable condenser connected in the oscillating circuit and arranged to give only a few cycles plus or minus from the base frequency of the crystal. Top and bottom aluminum plates complete the shielding.

Psychrometer with Motor-driven Fan

Elimination of errors due to varying air circulation (which may amount to 30% of the humidity determination) is accomplished by using a motor-driven fan to draw in a continuous sample of air past the wet- and dry-bulbs of a new psychrometer announced by the Johnson Service Co. As may be seen, it is of a modified Assmann type, with a mouth to which may be attached a sampling tube drawing air from a duct or apparatus difficult of access. It can be used in many places where the sling psychrometer cannot be

used. Thermometers are 8" long, etched-stem, of red-reading mercury form, range 30 to 110°F. divided in single degrees. Other thermometers optional.

C87 **"Fine Finishes Make Fine Products"** is title of leaflet covering Armco stainless steels. Summary of products is given. American Rolling Mill Co., Middletown, Ohio.

C88 **Phototube Relay.** Bulletin L gives data on Miles phototube relays. Applications are listed. Miles Reproducer Co., Inc., 112 West 14th St., New York, N. Y.

C89 **Maximeter and Maxipoint.** Bulletin describes the Maximeter, an instrument for determination of hardness, and Maxipoint, a system of heat treatment control. Greenlee Bros. & Co., Rockford, Ill.

C90 **Sperry Pilot for Automatic Flying.** 22-page booklet discusses the gyroscope, how the gyropilot operates and how to operate and maintain it. Sperry Gyroscope Co., Inc., Manhattan Bridge Plaza, Brooklyn, N. Y.

C91 **Market Trend at a Glance.** The Technigraph would have been the answer to a stock broker's prayer in boom years. This graphic instrument gives a trend picture of the market by computing the average of 25 representative stocks. Technigraph, Inc., 136 Liberty St., New York, N. Y.

C92 **Thermostatic Steam Trap.** 2-page leaflet on a trap for steady or fluctuating pressures 0-200 lbs. List prices, capacities, dimensions and spare part prices are tabulated. Sarco Co., Inc., 183 Madison Ave., New York, N. Y.

C93 **Meter for Flow, Temperature and Pressure.** 6-page folder DME650 describes a new meter for universal application. Features are listed. Foxboro Co., Foxboro, Mass.

C94 **Portable Pyrometer.** Bulletin illustrates the "Hold-Heet" pyrometer lance. Ranges and prices are listed. Russell Electric Co., 340 W. Huron St., Chicago, Ill.

C95 **Ohmite News.** December issue contains a description of new concentrically controlled rheostats. Ohmite Manufacturing Co., 636 North Albany Ave., Chicago, Ill.

C96 **Electrodialysis Cell.** Bulletin 710 gives data on the construction and operation of the modified Mattson cell as developed by the U. S. Dept. of Agriculture, Bureau of Chemistry and Soils. American Instrument Co., Inc., 774 Girard Ave., Washington, D. C.

C97 **General Radio Experimenter.** The feature article in the January and February issues of this house organ is entitled "Monitoring of Broadcasting Stations." General Radio Co., 30 State St., Cambridge, Mass.

C98 **Self-cleaning Nozzle.** Bulletin 76 describes this nozzle for use on water supply with air-conditioning and humidifying. Detroit Lubricator Co., Trumbull Ave., Detroit, Mich.

C99 **Rheostats.** Bulletin 1340 is devoted to sliding-contact tubular rheostats. Characteristics and applications, specifications and prices are given. James G. Biddle Co., 1211 Arch St., Philadelphia, Pa.

C100 **Solenoid Valve.** Bulletin 78 tabulates data on No. 683-R Solenoid Valve for refrigeration. Detroit Lubricator Co., Trumbull Ave., Detroit, Mich.

C101 **Cenco News Chats.** January issue contains a number of interesting items on laboratory apparatus. Central Scientific Co., 460 E. Ohio St., Chicago, Ill.

INSTRUMENTS
1117 Wolfendale St., Pittsburgh, Pa.

Have me supplied with a copy of each piece of Manufacturers' Literature listed below.

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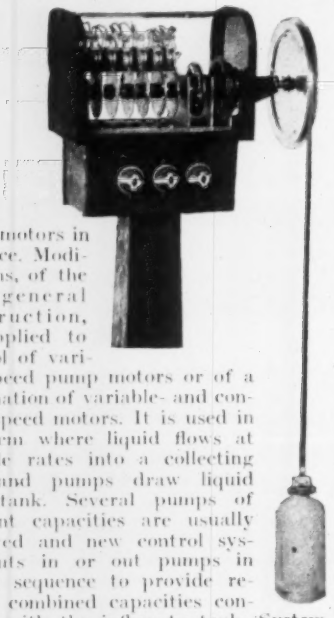
Motor Sequencing System

New Type L560 Control announced by Minneapolis-Honeywell Regulator Co. is a float-actuated electric switching system for starting and stopping constant speed

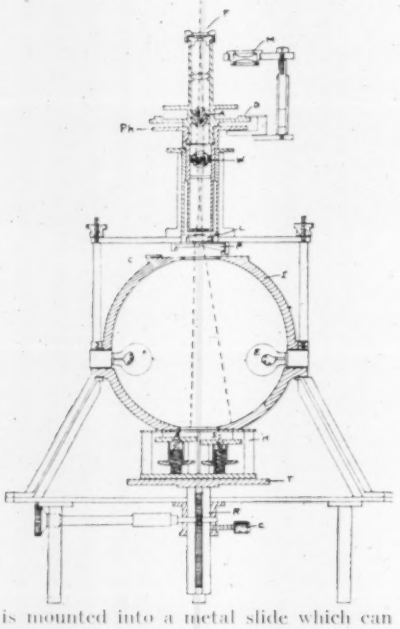


pump motors in sequence. Modifications, of the same general construction, are applied to control of variable-speed pump motors or of a combination of variable- and constant-speed motors. It is used in a system where liquid flows at variable rates into a collecting tank and pumps draw liquid from tank. Several pumps of different capacities are usually employed and new control system cuts in or out pumps in proper sequence to provide required combined capacities consistent with the inflow to tank. System consists of: (1) glass float; (2) sheave and shaft revolved by float; stainless steel tape; (3) shaft on which are mounted a series of cam disks, each carrying one or more cams depending on pumping sequence; (4) speed-reducing mechanism: provides means of adapting for any depth of tank by applying proper gear ratio; (5) adjustable lost-motion clutch between driving mechanism and disk shaft: provides differential between cut-in and cut-out; (6) Rocker-arms, etc.; (7) enclosed mercury switches; (8) set of transfer plugs and receptacles to transpose sequences; (9) adjustable tension spring, serving in place of a counterbalance, for revolving cam shaft when float rises.

Diffuse Illumination Color Comparator and Reflector

Originally designed by Priest, Lange and Judd in Colorimetry Section of Bureau of Standards where it is extensively used for reflection measurements and for comparison of colored objects, this new instrument, by applying suitable filters (red, green and blue) has proved also to be an efficient device for tri-chromatic color analysis. It is now placed on the market by Akatos, Inc. Equipment consists of a stand with sample holder, an illuminating sphere and Martens Polarization Photometer.

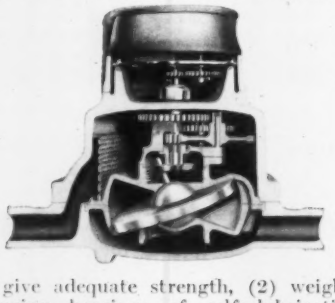
Triangular stand is equipped with a rack and pinion movement *R* for raising and lowering sample stage *T*. Special holder *H* can be provided for holding sample *S* and comparison standard *St* adjacent to each other, by means of spring plates whereby proper position for illumination and measurement of sample is obtained. Diffuse illumination is obtained by integrating sphere *I*, inside wall of which is coated with magnesium oxide. Four 6-volt bulbs *E* of shielded-filament type are used for indirect illumination: only light reflected from sphere wall falls on test object. Martens Polarization Photometer *Ph* fits into a draw tube in such manner that it can be adjusted for focus of object or being brought out of focus. Lens *L* serves for focusing. Prism arrangement *P*, for using sphere wall as a comparison standard for reflection measurements (as indicated by dotted lines of path of ray)



is mounted into a metal slide which can be withdrawn from optical path for measuring reflection also against a standard outside the sphere, placed adjacent to the sample.

Hot Water Meters

Three to ten times longer life is claimed for new model "Niagara" hot water meter of Buffalo Meter Co. Features are (1) a non-metallic nutating disk with internal metallic reinforcement



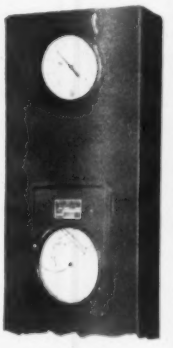
to give adequate strength, (2) weight-carrying bearings of self-lubricating type, (3) submerged gears carried on jewel bearings. New model comes in all sizes from ½" to 6" and is suitable for "all heated water-base liquids." Modifications are available for high pressures or temperatures, strongly acid or alkaline liquids, etc.

Electrostatic Voltmeters

Additions to line of electrostatic voltmeters announced by Ferranti Electric, Inc. include (1) instruments with full scales up to 18,000 volts, in single-, dual- and triple-range models; (2) instruments in 3¼" and 4" dial patterns up to 3500 volts. All are independent of frequency, wave form and temperature and may be used on a.-c. or d.-c. circuits.

Combination Feed Water Flowmeter and Boiler Water Level Indicator

A new meter to indicate and record both boiler water level and feed water flow has been developed by Bailey Meter Co. for use in boiler plants where it is desired to have both an indication and record of these factors on the operating floor. Combination meter consists of a standard Bailey Fluid Meter which indicates, records and integrates feed water flow and a 12" indicator with a dial type scale for boiler water level. Indicator is mounted directly above meter on a small feed



water panel as shown. If desired, combination meter can be located on individual boiler control panel. For purposes of comparison, it is desirable to have feed water flow and boiler water level recorded on one chart, coordinated as to time and interpretable without reference to additional records or calculations. Water level being a factor which should be frequently checked by operators, it is shown on large indicator. Continuous record of water level is said to be particularly valuable in case of boilers with small water storage space where "swell" due to sudden increase in load may cause slugs of water to be carried into superheater, or where "shrinkage" due to load decrease may cause level to drop so low that some tubes may be burned. In either event, permanent record helps determine causes of faulty operation.

Range Multiplier for Light Meter

For increasing the range of its Light Meter a device is announced by Westinghouse Electric & Mfg. Co., consisting of a screen which absorbs nine-tenths of the normal light and transmits 10% to

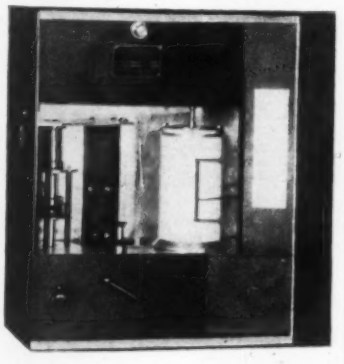
the photocell, thus decupling the scale range for measuring higher light intensities. The translucent screen decimates the flux reaching the photocell without altering the effective wavelength of the light transmitted, and its material is independent of the angle of incidence, so that it corresponds in effect to a lens stop in a camera. When not in use it conveniently clamps over the case of the Light Meter.

Simplified Unit-Constructed Boiler Control

The new "Metermax Unit Combustion Control" developed by the Leeds & Northrup Co. is built, assembled, factory tested and shipped as a unit, ready for installation. Installation costs are said to be "a quarter of former figures." Metermax Control is not essentially new but is an improved form of the L&N Metered Combustion Control. Employment of electricity as the power medium simplifies connections between panel and drive units. Four controllers are mounted on a panel. The Master controller connects to all boilers and balances steam pressure against an air loading pressure. The Fuel-feed controller, Air-flow controller, and Furnace Pressure controller at each boiler are each of the balance type with but one moving element, with push-buttons built into the case. The only connection between panel and each drive unit is a conduit carrying all control wires. Below the controllers on the panel are the fuel-air rheostat, load adjustment valve, transfer valve and selector switch—the arrangement assuring convenience. It is said that "Metermax Control" is priced to make it available to small boilers, although it includes electric-push-button control and interlock features heretofore associated only with expensive systems designed for the largest boiler units.

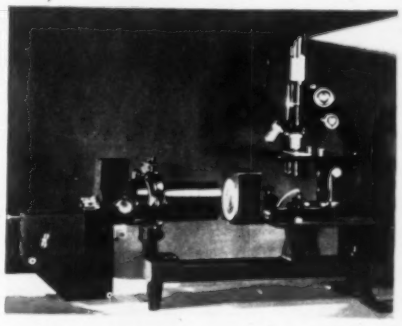
Direct Pressure Type Engine Indicator

Producing individual pressure-time diagrams and applicable to internal-combustion engines operating at highest speeds, new Type V "Research" indicator is latest addition to Commercial Engineering Labs.' series of indicators (see *Instruments*, Dec. 1933, page 233; Feb. 1934, page 40). A number of diagrams—each 12.56" long—can be superimposed on one chart for comparing effects of changed conditions on pressures at any points in cycle. Pressures below atmospheric are recorded to a scale of 1 lb./in.^{2} for ½" chart height, and above atmospheric to 1400 lbs./in.^{2} for 2" chart height. Provisions are made for installing additional pressure cylinders and tracer arms when it is desired to obtain high- and low-pressure diagrams simultaneously. Pressure elements are standard units in plain or "ignition" types. Among optional accessories are continuous paper feed, motor-driven phase-shifter, paper feed gears for acceleration studies, double-length card attachment, pressure-volume attachment whereby cards are produced which can be integrated with ordinary planimeter, etc.



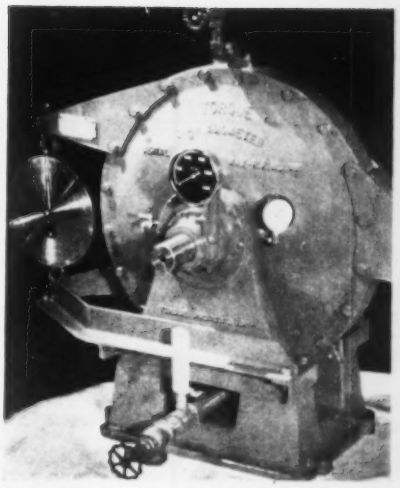
Micro-projector

Any available standard compound microscope may be used with the new "Model B Micro-projector" announced by Bausch & Lomb. It consists of a metal base supporting the microscope and light source, a clockwork-feed arc lamp, a water cell, a mirror, a reflecting prism and a metal shield. The arc lamp, said to be far more efficient for the purpose than any incandescent source, operates in connection with a rheostat of either 4½ or 8-amp. capacity, and will function on either d.c. or a.c., d.c. being preferable. The horizontal microscope supporting plate permits the use of any model or make of microscope. A mirror is mounted at the proper angle to illuminate the microscope condenser. The reflecting prism fits over the microscope eyepiece to direct the beam of light, and the metal shield prevents stray light from reaching the screen. Any compound microscope having an Abbe substage condenser can be used. For instruments not provided with condensers, Bausch & Lomb offer an attachable model consisting of a single lens element mounted in a metal sleeve which attaches to the undersurface of the microscope stage. This condenser is suitable for objectives of 16mm., 8mm., or 4mm. focus and can be removed when low-power objectives of long focus are used. A well-darkened room is desirable for best results, a 5-ft. screen image being possible. Regular microscope eyepieces are satisfactory, but the special projection eyepiece of 3× permits a 20-ft. projection distance. Operation is simple. Knurled headed screws are provided to allow for critical centering of the arc lamp; the lamp condenser is adjustable in a focusing sleeve. Once these are in correct position, there is little adjustment to make.



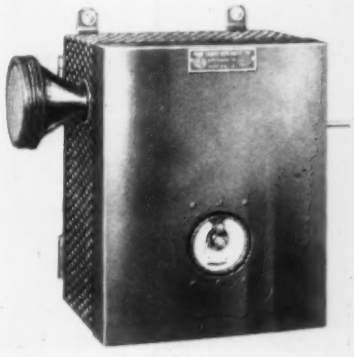
Water Dynamometer

"Torque" dynamometer announced by Torque Products Co. is of hydraulic absorption type, for measurements of torque and horsepower of engines, motors, turbines, water wheels, speed reducers, brakes, tires, belts, couplings, clutches, etc., also for endurance or breakdown tests and for breaking-in engines. It is claimed that this dynamometer is as smooth and accurate as the electrical type, more flexible and considerably lower priced. Both stator and rotor are mounted on annular ball bearings. Scale equipment, connected to floating stator, measures torque applied to rotor shaft, in either direction of rotation. Water consumption is nominal. Makers state that they have a size and speed to meet any testing requirement and that operation is as simple as turning a water faucet.



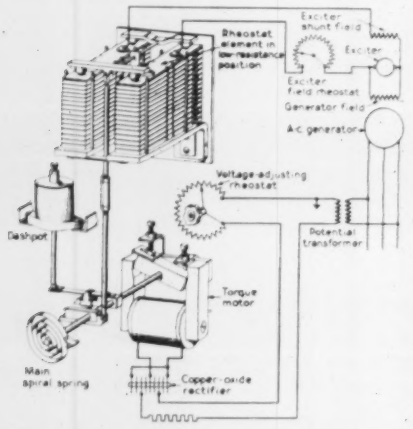
Carbon Monoxide Alarm

Said to be the only available device of its type, new MSA Carbon Monoxide Alarm announced by Mine Safety Appliance Co. gives a warning when CO concentration reaches 0.02% at which point a few hours' exposure would be required to produce first symptoms of poisoning. A small fan, direct-connected to a 1/80 h.p. motor, pulls in a continuous sample of air at rate of 20 liters per minute through a replaceable filter for trapping entrained dust. Air passes over electric heater coils and enters a divided insulated cell containing active and inactive "Hopcalite," respectively, in its two compartments. CO present is converted into CO_2 with liberation of heat in proportion to concentration. Heat liberated is measured by thermocouples and is indicated on a dial graduated from 0 to 0.02% CO. When pointer reaches the 0.02% mark, a magnet pulls it against a stop-post, which closes the alarm circuit. Ringing of gong continues until pointer is turned back by hand. New device is built for 24-hr. a day operation, consumes 100 watts, is said to reduce compensation costs in industrial establishments.

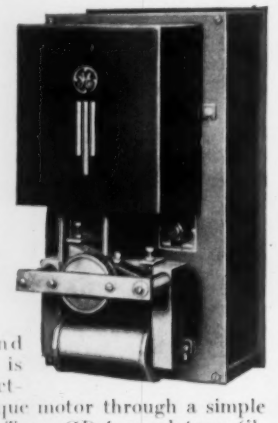


Generator Voltage Regulators

A complete line of a.-c. and d.-c. generator voltage regulators announced by the General Electric Co., said to be radically new and simple in principle and operation, consists of four types of exciter-field rheostatic regulators, all fundamentally alike but with design modifications suited to application and class of service. In all four types, there are no vibrating contacts, the voltage-sensitive element being a form of torque motor balanced against a spring, and



controlled by generator voltage. At any applied voltage within the range of the regulator, the armature of the torque motor assumes a corresponding deflection against the restoring torque of the spring. This element then remains motionless unless a change in voltage occurs, in which case a proportional change in deflection takes place. In Type GDA and GDD, a dashpot linked to the moving element prevents oscillation and provides dead-beat operation. In Types GFA-4 and GFD-2, a magnetic damping device performs the same function. Response of the torque motor element is fast and possesses a flat characteristic with respect to load, frequency, and temperature. In all the new regulators, the regulating system remains at rest unless an actual change in generator excitation becomes necessary to maintain voltage. The two direct-acting regulators, Types GDA and GDD, employ a rheostatic element of new construction which provides a smooth change in resistance from zero to maximum in a great number of very small steps. This rheostat is small and compact and is operated directly by the torque motor through a simple linkage. (1) *Type GDA* regulators (illustrated) are for voltage control of small- and medium-sized a.-c. generators, synchronous condensers, and synchronous motors. (2) *Type GDD* regulators are for the control of voltage, speed, or current with small- and medium-sized d.-c. machines. (3) *Type GFA-4* regulators have high-speed features and are considered especially suited to the control of large and important synchronous machines. Excitation is controlled by automatic adjustment of the exciter field rheostat and by high-speed relays which cut in or out the entire regulating resistance in the exciter field only in case of large changes in voltage. In the Type GFA-4, the voltage-sensitive element is a polyphase torque motor responsive to the average voltage of the polyphase circuit to which it is connected. Rotating cam contacts provide positive mechanical anti-hunting independent of exciter voltage or electrical characteristics of the machine or system under control. The complete standard Type GFA-4 regulating equipment consists of the regulator proper, a motor-operated exciter-field rheostat, with field-reducing resistor, a relay panel with a normally open and a normally closed high-speed relay, an adjusting rheostat, and a transfer switch. (4) *Type GFD-2* regulator is intended for voltage, speed, or current control of large d.-c. machines. It is essentially the same as the Type GFA-4, except that the torque motor is a d.-c. device. It may be obtained with or without the high-speed features.

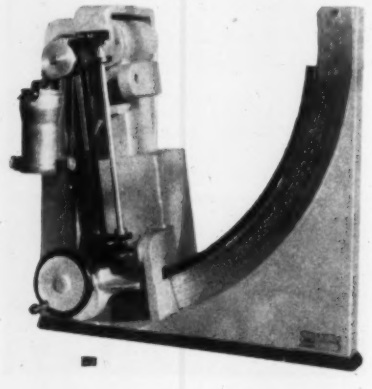


Crystal Microphone

Exceptionally flat frequency response and elimination of all maintenance expense are claimed for new "Type G" piezoelectric crystal microphone brought out by The Turner Co. under Brush Development Co. patents. Requires neither adjustments nor energizing circuit. Crystal is mounted on "a new type of resilient material impervious to heat and moisture."

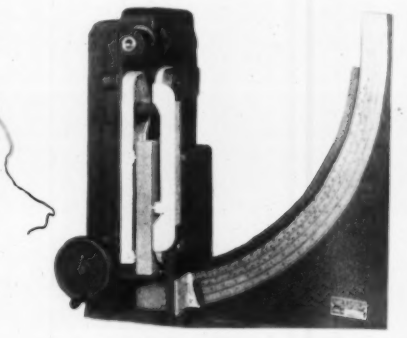
Sand Testing Instruments

The following instruments have been brought out by Harry W. Dietert Co. For *Tensile Strength*: A tensile specimen tube holder bolts to pivot shaft of Type C. P. machine. A hardened steel base holds it rigidly during test. The loading mechanism is mounted on an aluminum frame having 2 hardened studs which enter upper and lower test position holes



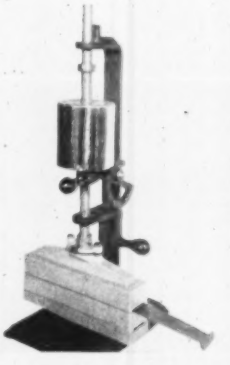
of pusher arm of strength machine to hold it in position. A steel shaft supports the pendulum weight on its lower end. On upper end of shaft the load is transferred through a bronze ball chain to upper half of sand specimen in tensile specimen tube which consists of tube proper, specimen grip and cup pedestal. Specimen grip which holds upper half of sand specimen seats itself into the tube proper on a self-freeing taper. Cup pedestal fits around bottom of tube holding specimen grip in place while ramming sand in tube. Sand sample is placed in tensile specimen tube and rammed. Cup pedestal is then removed and specimen tube is attached to tensile test accessory. Sand specimen is loaded by turning hand wheel of Type C. P. strength machine and recording maximum dry shear scale reading as grams tensile strength.

For *Transverse Core Strength*: Accessory consists of a double core support arm and a single core support arm. The former is attached to the pusher arm while the latter is attached to the loading

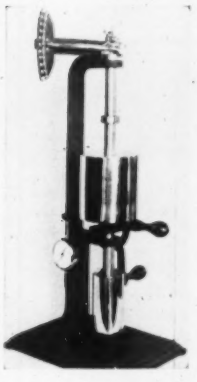


weight of the strength machine. Supports on double support arm are pivoted to secure alignment with core specimen. The load on the core specimen is read directly from the dry shear scale of the strength machine.

Transverse Strength core box consists of: A hardened steel faced aluminum cross-head with attaching clip for rigidly attaching cross-head to plunger of sand rammer. A sand hopper to hold surplus



of core sand. A spring steel cutoff knife to size core to 1" height. A two-part aluminum core box allowing easy removal of core from core box. Core drying plates on which core specimens are rammed and by which they are handled before baking. A steel anvil forming a support for the core box assembly. A strike-off template used to level core sand in sand hopper. Cores as rammed with this equipment are suitable for either research or control test.



Flowability Indicator consists of a dial indicator attached to the sand rammer. Indicator stem rests against cross-head of rammer and registers movement of rammer plunger between fourth and fifth drop as flowability.

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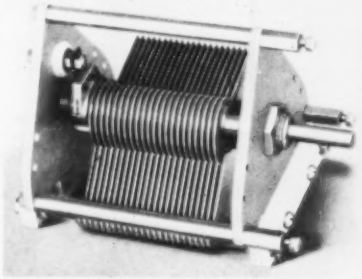

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Full details in Bulletin 936-B.

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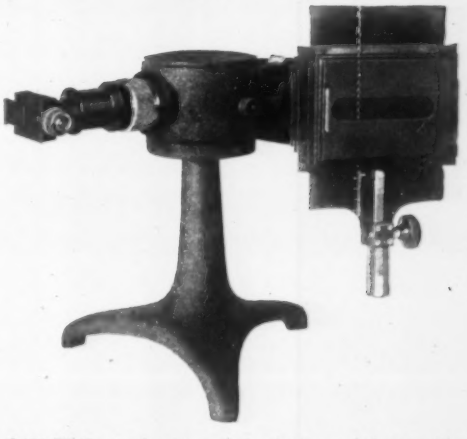

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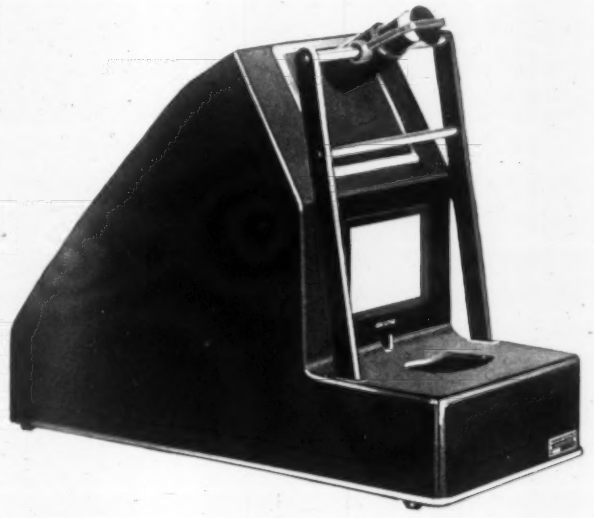

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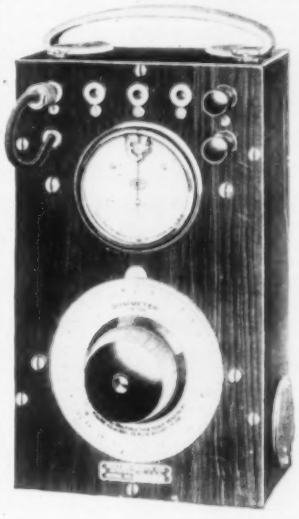

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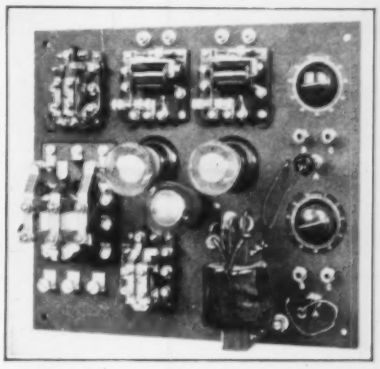

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